UPPSALA UNIVERSITET
LIMNOLOGISKA
INSTITUTIONEN

ULF KARLSTRÖM

ENVIRONMENTAL FACTORS, DETRITUS AND BOTTOM FAUNA IN THE RICKLEÅN - A NORTH SWEDISH FOREST RIVER

UPPSALA 1978

ABSTRACT

U. Karlström. Environmental factors, detritus and bottom fauna in the Rickleån - a north Swedish forest river.

In order to give a description of a forest river in North Sweden, field studies and field experiments were carried out during 1973-76 in the Rickleån. Within this study, particular interest was focused on the sources, transport and turnover of detrital matter.

In general terms, the Rickleån ecosystem deviates in several aspects from commonly studied, smaller woodland streams. The impact of the terrestrial vegetation is considerably less on a yearly basis than in small streams. On the other hand, the main contributors to the detrital pool of the river are the water mosses.

The existence of thick carpets of water mosses and relatively deep, multi-layered beds, furnish the Rickleån with a considerable capacity to retain particulate organic materials. The fluctuations of fine particulate matter are generally small. Small particles strongly dominate the composition of the seston.

The bottom fauna of the rapids exploit the continuous and steady supply of fine particulate matter as food. The filter-feeders dominate the benthic communities of the rapids.

Although the Rickleån harbours a rich benthic fauna and during the summer period may reach a high mineralization rate, it is apparent that a very small amount of fine particulate organic matter is metabolized in the river. The dominant feature of the Rickleån is the large flux of materials through the stream ecosystem.

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BY

ULF KARLSTRÖM

INSTITUTE OF LIMNOLOGY, UNIVERSITY OF UPPSALA, SWEDEN

AUGUST 1978

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1 INTRODUCTION

Lotic limnology is only a minor part of limnological research throughout the world. However, over the last 20 years this sector has developed strongly, especially in a holistic direction (Hynes 1975). One of the pioneering works was the Silver Spring investigation (Odum 1956) which was followed by works dealing with the energy flow and the relationships between several trophic levels within a stream ecosystem. The importance of detrital food chains was particularly emphasized (e.g. Nelson & Scott 1962, Coffman et al. 1971, Fisher & Likens 1973). The base of the detrital metabolism dealt with in these works was allochtonous material, primarily particulate organic matter from the surrounding terrestrial system. Leaves originating from the riparian vegetation play the dominant role in many small streams. It has been shown that the leaves constitute an excellent substrate for heterotrophic microbial growth (Kaushik & Hynes 1968, 1971, Cummins et al. 1973, Iversen 1973). Small streams may receive large amounts of allochtonous matter and thus become strongly heterotrophic systems, i.e. with a P/R ratio considerably less than 1.

Rivers are likely to behave rather differently to small streams, as they differ in such important aspects as the quantity of the particulate transport and the role of the riparian vegetation. Since most stream research has been carried out in small streams I felt a need to work out information about the sources, transport and turnover of detrital matter in a river. The Rickelån, a north Swedish forest river of moderate size and with a smoothed discharge regime, was chosen as being suitable for an investigation of this nature. In general, running waters of the northern coniferous forest region have been little investigated. Admittedly, north Swedish rivers of both mountain and forest origin have been discussed earlier in connection with several, mainly faunistic, studies (Brinck 1949, Müller 1953 , 1954a, 1954b, Carlsson 1962, Ulfstrand

1968a, 1968b, 1969). During the period 1960-1966 the station of the Salmon Research Institute on the Rickleån, which became the Rickleå field station of Umeå University in 1967, has also contributed data (e.g. Österdahl 1969, Södergren 1969). After the affiliation of the station to the university, the fields of research were widened to include a variety of limnological aspects (Göthberg & Karlström 1975). However, a more comprehensive account of a forest river does not appear to exist. Therefore, a general objective of the present study is to give a detailed description of a forest river - The Rickleån - and its responses to drainage basin processes.

2 GENERAL DESCRIPTION

2.1 The drainage basin and its river

The Rickleån river drainage basin (no 24) is one of the 118 main drainage basins of Sweden. It has a total area of 1673 km^2 and includes both the coast and a part of the taiga belt of northern Sweden. The drainage basin has an elongated, narrow shape, at a maximum stretching 110 km in a NW to SE direction, where the river Rickleån enters the Gulf of Bothnia at $64^{\circ}10'N$ (fig 1). The lake area constitutes 9 % of the basin. The pre-quaternary rocks of the basin consist of veined gneisses, mainly sedimentary and granite gneisses. Granite gneisses dominate in the lower part of the basin (Hjelmqvist 1953). Till is the main quaternary deposit and along the water courses clay, silt and very fine sand also contribute to the composition of the soils. The elongated drainage basin covers three different soil regions schematically distributed along a coast inland gradient. From the upper part to the coast the areas covered by mires are 35, 30 and 20 %, respectively, in these regions. The coast region is made up of 20 % exposed bedrocks, while the share is 10 % in the other two regions (Lundqvist 1953).

The meteorological conditions of the basin change somewhat along a coast inland gradient. The climate is characterized

by long, moderately cold winters, and low precipitation (tab 1). Cumulative values for monthly precipitation from the field station at the mouth of the Rickleån is given for 1973-76 (tab 2).

Lake Bygdeträsket (64°26'N, 20°28'E) is the largest lake, 29.2 km^2, and is separated from Lake Göksjön, 10.3 km^3 (Wersén 1928) by only a small waterfall. The two lakes are situated slightly below the middle region of the drainage basin (fig 1). Lake Bydgeträsket (131 m a.s.l) is drained by an ungraded, fifth-order stream, the Rickleån. This watercourse is relatively short, 48 km in length. The river course alters schematically in a step-wise manner between rapids and slowly flowing sections (fig 2). The rapids are generally 20-30 m wide and 0.5-2 m deep, while the slow-flowing parts are 30-50 m wide and 2-3.5 m deep at mean water levels.

From the lake to the small town of Robertsfors there are three long rapids, Storlångforsen, Faranforsen and Isakfäbodaforsen, the combined length of which constitutes 3.9 km, or 13 % of the length of this part of the water course. Below Robertsfors there are several smaller rapids which constitute 3.8 km or 25 % of this part of the river. The rapids make up 16 % or 7.7 km of the whole river.

The Rickleån can be separated into three major habitats; rapids, streaming sections and slow-flowing sections (tab 3). The rapids are built up of boulders and large stones, with finer material down in the river bed. Water mosses, among which are found *Fontinalis antipyretica* Hedw., *F. dalecarlica* Br. Eur., *Hygrohypum ochraceum* (Turn.) Loeske, and *Hypnum lindbergii* Mit. (Johnsson 1976), are abundant. The streaming sections are intermediate in terms of water velocity and have hard bottoms of clay and gravel. These areas are usually very poor in primary and secondary production. Slow-flowing sections have soft bottoms and the submersed vegetation is strongly developed. Littoral zones are lacking in the rapids, but occur widely in the other two habitats. Areas with soft, organic bottoms, 5-10 m wide and 100-200 m long, may border the river; *Equisetum fluviatile* L. dominates, and closer

to the banks *Carex aquatilis* Wahlenb. and *C. vesicaris* L. occur.

The Rickleån flows through coniferous forests and farmland. Agriculture dominates around Lake Bygdeträsket and below Robertsfors. River sections borded by farmland have usually a zone of deciduous, riparian vegetation (*Betula pubescens* Ehrb., *Alnus incana* (L.), *Populus tremula* L. and *Salix* spp.).

The discharge of the river shows a strong seasonal variation, althrough the runoff pattern is smoothed due to regulation throughout the drainage basin. Maximum spring discharge is estimated to 160-180 m^3 s^{-1} at the lowermost power station at Robertsfors. The spring flood lasts for approximately one month, chiefly May. The water level amplitude is roughly 1.5 m at the field station. Low discharge occurs during summer and winter. Summer discharge usually ranges from 3 to 10 m^3 s^{-1}. No continuous recording of the discharge exists. Records of the amount of water passing the turbines in the lowermost power station are taken weekly, and can be obtained from the company upon request (MoDo AB, Örnsköldsvik). These records should be regarded more as estimates than precise measurements, and they do not include the spring flood period.

The ice generally breaks at the end of April. Maximum water temperature, usually 20-21 ^{o}C, rarely 23-24^{o}C, is reached in July-August. The slow-flowing parts of the river are generally covered with ice from the middle of November. Maximum ice thickness is about 1.5 m. Weekly records of the water temperature are given for 1972-74 (fig 3).

The impact of man's activity on the Rickleån drainage basin has been and still is considerable (Fahlgren 1963). Around the year 1000 land elevation gave the basin approximately its present coast-line. At this time the coast was colonized, but the settlements were very few. However, the colonization of the inland began during the 13th century, indicating that the coast was already extensively colonized. Written documents about the salmon fishery in the Rickleån exist

from 1337. Forest clearing to provide farmland decreased markedly about 1550 and people left the poorer, more outlying, land. A new period of active land reclamation took place 1780-1850 due to increasing population demands. During this period ditching and lowering of the water table of some lakes occurred, especially in the lower part of the drainage basin. A foundry with a blast-furnace was built at Robertsfors in 1760 and a tilt-hammer in 1783. Around 1800 the forestry became important and saw-mills were erected in several places, e.g. in Robertsfors. The coastland forests had been cut down to a large extent, and logged timber had to be taken from the inland, to the W and NW of Lake Bygdeträsket. To faciliate floating the Rickleån was cleared down to Robertsfors, as well as other smaller water courses, and several small dams were built. Waste products from the saw-mill at Robertsfors also affected the river. In 1893 the first hydro-electric power station was built at Robertsfors. A paper pulp factory, erected in 1904, caused serious pollution downstream of Robertsfors and the fishery was destroyed. After the close-down of the factory in 1948, the fishery recovered successively. The floating of timber down the river stopped in 1961.

Today the Rickleån is influenced by the run-off and drainage water from surrounding farmlands, and to a much lesser extent by sewage water, mostly treated, from the communities of Bygdsiljum (600 inhab.) and of Robertsfors (1850 inhab.). A serious cobolt pollution from a factory in Robertsfors manufacturing industrial diamonds took place during 1966-75. The pollution effects, mainly reduction of bottom fauna and extinction of salmon and sea trout, are extensively discussed by Södergren (1976).

One hydro-electric power station at the outlet of Lake Bygdeträsket and three at Robertsfors are operated today. Several small dams in the river system result in some moderation of the natural dramatic run-off oscillations.

2.2 Physical-chemical environmental factors

Sampling sites

Most of the samples were taken at the field station, which is situated at the mouth of the Rickelån (fig 1). A former fish-trap functions as a bridge and enables the sampling to be performed in the middle of the channel.

For some of the parameters samples have also been taken upstream of Robertsfors, at the uppermost power station (Fredriksfors, fig 2).

All samples have been taken in turbulent, well-mixed water, where no micro-gradients are assumed to occur.

pH

The pH was measured up to three times a day except weekends, during 1974-76 at the field station with a glass electrode (Metromen) and for a short period in 1974 with a Beckman Electromate pH meter. Water samples were also transported to Umeå once or twice a month around 4 p.m. and were kept overnight at +2°C, after which they were measured with a Beckman Electromate pH meter (1974-75) and with a Radiometer PHM 62 (1976).

In spite of their simplicity the routine pH-measurements at the field station met with difficulties in 1974. A new pH-meter (Beckman Electromate) was found to drift up to 1.0 unit during 30 min of measurements. Consequently only values from 1975-76 are reported here.

If the immediate readings at the field station are compared with those of the stored samples, some deviations become apparent. During summer and autumn, stored samples show values about 0.3-0.5 units higher. It is not known whether these higher values are due to a storage artifact.

The results from the immediate measurements illustrate the seasonal and, to some extent, the daily variations (fig 4). Around February very low values can be found, e.g. 5.2-5.4.

After this the level reaches up to or above 6.0. However, after the spring flood a new drop usually occurs, due to the melting of the snow. Melt-water from the field station has frequently been recorded to have a pH of 3.5-4.5. However, the spring "pH-shock", a severe threat to many Scandinavian lakes, does not seem to be dramatic in the Rickleån. After the spring flood, the pH increases and seems to stabilize around 6.4-6.5, with some recorded maximum values of 6.6-6.7. Autumn rains and floods may cause sudden drops. During the early winter the pH level decreases.

Conductivity

Samples for conductivity determinations were taken once a week from the field station during 1975-76. The conductivity was measured at 20°C with a Normameter in 1975 and with a WTW LF39 in 1976.

The conductivity fluctuates moderately in the Rickleån (fig 5). Peak values of 4.5-5.0 mS m^{-1} are recorded at the very beginning of the spring flood, during heavy rains and sometimes during the early winter. In spring dilution from melt-water, poor in electrolytes, causes a drop in the conductivity to around 30. A model value during the years of the investigation is around 3.5 mS m^{-1}.

Major constituents

Major constituents were not included in the routine programme for the field station. However, once a month untreated water samples were sent to the Limnological Survey of the National Environment Protection Board, Uppsala for determinations of Ca, Mg, Na, K, HCO_3, SO_4 and Cl. The methods are described by Ahl (1972).

The results are shown as mean values for 1970-75, both from the field station and from Robertsfors (tab 4). The composition of the cations deviates from the standard composition (Rodhe 1949) as the calcium content is relatively low. This can be attributed to the calcium-poor bedrocks and

soils prevailing in northern Sweden. The cation composition of the Rickleån water follows approximately the composition of the North Swedish lakes no 101-165 reported by Rodhe (1949, 1958) on the basis of Lohammar's (1938) extensive survey of Swedish lakes. These lakes, however, have a somewhat higher percentage of magnesium than the Rickleån.

The anions also deviate from standard composition, since sulphate is the prevalent anion. The dominance of sulphate may be due to several factors. The low pH during part of the year presses the equilibrium of HCO_3-CO_2 to the CO_2 side and thus changes the proportion between bicarbonate and sulphate. Sulphur-rich deposits around the Baltic Bay exposed by land elevation frequently result in relatively high contents of sulphate in coastal lakes (Hannerz 1934, Vallin 1953). This might perhaps be reflected in the slight differences in the composition of sulphate between the two stations on the Rickleån (tab 4). Hutchinson (1957) states that the dominance of sulphate can in some cases be attributed to FeS_2 in peat deposits.

The seasonal change of the major constituents is illustrated by the coefficient of variation for Ca, HCO_3 and SO_4 (tab 4). The variability is more pronounced at the lowest station, especially for anions. Bicarbonate has its lowest concentration during May, due to the addition of melt-water with a low pH. Maximum bicarbonate concentrations are found during June and July. Sulphate concentration actually shows a reversed picture, with the lowest amounts during June and July. Maximum values are found in the early winter, October-December.

In summing up, the Rickleån can be characterized as a calcium sulphate water.

Minor constituents

Minor constituents were determined approximately twice a month during 1974-76 from the station just above Robertsfors and from the field station. The water samples were

filtrated through Whatman GF/C filters and stored frozen until examination. The freezing procedure affects the samples by destroying materials, e.g. bacterial cells that have passed the Whatman filter, but the Rickleån is fairly unproductive as regards bacteria and, therefore, the freezing artefact was assumed to be small.

NO_2+NO_3 were analyzed according to Wood et al. (1967). Molybdate reactive phosphate was analyzed mainly according to Murphy & Riley (1962) and Stephans (1963). Thus, phosphate in the following text refers to the fraction of phosphorus reactive to molybdate.

The concentration of NO_2+NO_3 ranged from 14 to 160 µg N l^{-1} (tab 5). This amount represents almost entirely the nitrate fraction; the concentration of NO_2-N ranged from 1.3 to 2.3 µg l^{-1} during August and September 1974, making 1.7-3.2 per cent of the sum of NO_2 and NO_3. There is a marked seasonal pattern with minimum values during June-September, when the primary production has its peak. During 1974-76 it seems that the nitrate is never depleted, although shorter sampling intervals are necessary before a definite statement can be made. The concentration levels are generally higher at the field station than at the station upstream of Robertsfors and I interpret this to be an effect of urban concentration and increased farming along the lower reaches of the Rickleån. However, during March-May 1976, a period including the spring flood, the concentrations are slightly higher at Robertsfors. The reason for this is not clear.

Phosphate concentration in the Rickleån is low, but not extremely low as in ultra-oligotrophic waters (Wetzel 1975); it ranges from 1.6 to 10(20) µg PO_4-P l^{-1} (tab 6). Some contaminations, probably originating from the sample bottles, were recorded from Robertsfors (marked with brackets in the table). Differences between the two stations were noted on some sampling occasions, but there is no evidence of higher concentrations downstream of Robertsfors. No seasonal pattern can be discerned. It may be concluded from existing data that no depletion of PO_4 seems to take place and thus

the situation is similar to that for nitrate.

Turbidity

Water samples from the field station were taken approximately twice a month during 1976 for turbidity measurements. Sampling intervals were shorter during the spring flood. The turbidity was measured both for untreated and filtrated samples. The measurements were performed with a Hach model 2100 A and expressed as nephelometric turbidity units, NTU (the unit has been calibrated against formazine by the manufacturer).

The turbidity measurements show good concordance with the load of fine particulate material in the Rickleån (tab 7). The spring flood increases the load considerably and during summer and autumn a relatively high level is maintained. During November 1976 construction work began at Robertsfors to install a new hydro-electric turbine. This caused very high, and rather unrepresentative records. Consequently, the values of November 21 are bracketed. Lowest turbidity recordings occur during January-March.

The turbidity of the filtrated samples varies little, but still there is a tendency that it follows the change of the unfiltrated samples. Probably this reflects the inability of glass fiber filters to retain small particles when only small volumes (<0.5 l) are filtrated.

Optical density

The optical density was read three times a day except weekends at the field station during 1974-76. The measurements were performed at 420 nm with a Beckman spectrophotometer using 5 cm cuvettes. Both untreated and filtrated (through Whatman GF/C) samples were measured.

The optical density is a measure of absorption and scattering of the light beam passing a defined water column. The difference between unfiltrated (UF) and filtrated (FI) samples is generally small, 8-12 % of the UF samples. When

the fine particulate load is relatively high, e.g. during floods, the differences may reach 20-31 % (fig 6). This implies that the FI-values generally follow the curve of UF-values, although the peaks are cut and the FI curve is somewhat smoothed. Consequently, the optical density should be regarded as a poor estimator of seston content. In the Rickleån water most of the absorption is due to dissolved or colloidal materials, which most probably can be referred to as humic compounds.

The optical density for untreated samples is given as weekly means for 1974-76 (fig 7). Mean values range from 0.130 to 0.310. The seasonal pattern is obscured due to a large variation between the years of investigation.

The summer and autumn rains of 1974 were exceptionally heavy (tab 2) resulting in high water levels and high discharge in the Rickleån. The optical density increased successively from approximately 0.150 to 0.260. This increase was strongly correlated to weekly precipitation (fig 8). The high values prevailed during the winter 1975. Not until the late winter, prior to the spring flood, did the readings of optical density decrease. After the flood and during the summer the records again decreased, and this was observed both in 1975 and in 1976. Autumn rains, as in 1975, influence water colour and the levels increase.

The Rickleån water contains large quantities of humic substances (see section 5.1). It is known that the colour of humic compounds changes in response to changing environmental conditions (Ohle 1934, Åberg & Rodhe 1942). By means of artificial UV-radiation Gjessing & Gjerdahl (1970) demonstrated the effect of photo-oxidation on the removal of humic substances. Several of these environmental factors, e.g. pH, insolation, are subjected to seasonal variations and thus also the water colour shows a pattern of seasonal variation.

In spite of large differences between the years a seasonal cycle may be discerned. It seems that these seasonal cycles

are superimposed upon long-term hydrological cycles ranging over several years, as can be seen in the successively decreasing levels of the optical density from 1974 to1976 (fig 7).

3 SOURCES OF DETRITUS

3.1 Introduction

Particulate organic materials, which enter a stream, will be subjected to microbial infestation. Complexes of micro-organisms and organic material are termed detritus.

The organic material in the Rickleån originates from several sources. The terrestrial environment, for example, provides leaves, flowers, fruits, seeds, twigs, branches, needles etc. In this allocthonous group of components, the leaves are quantitatively the most important. The impact of the leaves on the Rickleån will be dealt with in section 3.2

The autocthonous material consists of littoral and submersed vegetation. Apart from a pilot-study in 1973 no investigation has been carried out to measure the input to the Rickleån from these components. However, an extensive investigation of the composition, load and transport of large particulate organic matter (LPOM) has been made. Since a part of the total LPOM pool in the river will be turned into small particles, the sources of detritus may be elaborated from the LPOM transport data. Consequently, a section on the littoral and submersed vegetation has been included here (chapter 3.3).

Finally there is evidence that a part of the dissolved organic matter (DOM) pool is transformed to a particulate phase, mainly through flocculation (Lush & Hynes 1974). None of the data from the Rickleån directly support this proposition, but a general discussion of the role of DOM is included in section 5.1.

3.2 Terrestrial vegetation

The aim of this section is to provide data on the impact of the terrestrial vegetation on the Rickleån and to enable comparison with other streams reported in the literature. It was realized from the beginning that the data collected could not cover the whole river, but would at least deal with some representative sites.

Methods

Leaf-traps covering an area very close to 1 m^2 were used. The trap consists of a square frame of wood to which is attached a net forming a bag (mesh size approximately 1.5 mm). The traps are placed horizontally approximately 1 m above the water surface. The sampling interval was 1 week. The traps are easily sampled by turning the net-bag inside out. Observations on days with strong winds confirmed that material was never blown out of the traps.

One common limitation of traps is that the catches they give are too high or too low due to changed micro-gradients around the traps. As regards the leaf-traps at the Rickleån several observations were made in the field, but a falling leaf was never observed to change direction when it reached the vicinity of the traps. It also appeared that the mesh-size of the nets is sufficiently large to reduce any "trap-effect" due to the winds.

During 1976 a complementary type of trap was used to estimate the leaf-fall directly to the ground and the amount of leaves blown to the edge of the water. These traps were plastic cases measuring an area of 50 x 51 cm (approx 0.25 m^2) with a height of 7 cm. They were placed directly on the ground.

The leaves were dried at 60°C for 24 h, and weighed to the nearest 0.001 g. Besides the leaves a small amount (<1% of total catch) of seeds and coniferous needles was caught. Occasionally twigs and branches were found in the traps. This type of material was noted but not included in the present calculations.

In small streams and wider slow-flowing streams it is convenient to place leaf-traps as a transect in order to get representative values for a section. For practical reasons this is not a feasible method for wider, fast-running streams. It was thus necessary to determine how far out in the river leaves can be blown. This was investigated in 1975 by placing the traps at two sites (A, B) in the vicinity of the field station. At site A a rope was put up across the river and 5 traps were mounted to the rope at distances to the bank of 1, 3, 5, 7 and 9 m (fig 9). On this side of the river the rope was secured around a large tree.

At the other site, B, three rows of 5 traps each were placed at distances from the bank of 2.5, 6 and 10 m (fig 9). This site was more exposed to winds than site A.

Based on the results from 1975, a 10 m zone was defined at sites C and D as the area where the bulk of the leaves were deposited. The amount of fallen leaves was summed up for each meter of the 10 meter transect. Values between rows of traps were calculated by interpolation.

Results

The leaves at site A were not blown far out in the river (fig 9). The traps placed 7 and 9 m out from the bank caught negligible amounts of materials. Even the trap positioned 5 m from the bank received a small share of the fall; only 2.8 % of the total catch.

At site B leaves were blown farther out in the channel. Still, at 10 m out in the river the third row of traps caught 7.5 % of the catch of the innermost row (fig 9). The bulk of the leaves entering the Rickelån, however, fall within a few meters of the bank.

Differences between the leaf-fall periods in 1975 and in 1976 were small (figs 9 and 10). However. the leaf-fall was more concentrated in 1976, mainly to the weeks 40 and 41.

At sites C and D three rows of traps and plastic cases were arranged to catch materials entering the stream from different types of riparian vegetation. Site C represents a bank section with medium-sized trees and shrubs. Site D represents a bank area covered only with shrubs (fig 10). A third type of bank vegetation may be recognized by using the data from site A, collected in 1975. Here the traps were positioned just below a large birch, thus indicating a plausible maximum value of leaf input.

These three types of bank vegetation have been tabulated and expressed as leaf-fall in g m^{-1} shoreline and g m^{-2} for river sections of 25 and 40 m width, respectively (tab 8). The figures in the table have been obtained by multiplying the measured leaf-catches by two, thus enabling a preliminary approximation of the leaf-fall. The value from site A is included in table 8 only to give an example of an extreme site with very high leaf-catches.

Discussion

The leaf traps and the arrangement of the traps seems to give reliable estimates of leaf input to the Rickleån at an acceptable cost of time. However, two possible sources of error should be observed.

The input data embrace only the autumn leaf-fall, and thus fail to include the slight spring-summer "pulse" of leaves, flowers and fruits. Furthermore, the input from coniferous needles and the spring wash-out of leaves from the banks are not included in the given data from the Rickleån. These omissions thus cause some underestimation of the true value for terrestrial input.

Fisher & Likens (1973) reported that the autumnal leaf-fall in a hardwood forest accounted for 90 % of the total leaf input, and 54 % of the total input of terrestrial matter during a year. Branches and twigs were the second most important component. Wood tissues have a very long "biological half-life" and it would be very misleading to compare leaf and wood tissue on a weight basis.

Although the Rickleån drains a basin dominated by coniferous forests the input of needles is relatively low; only small quantities are caught with drift-nets (only a minor portion of the "remaining", tab 9 and also section 3.4).

The input of leaves or leaf-fragments due to spring wash-out of the river banks is probably more important than the spring-summer "pulse" or the needles. Of course, this input is highly variable from year to year depending on the flood condition during the previous autumn. Including these additional sources, the total terrestrial input to the Rickleån will be higher than stated in table 8, probably in the order of 20-30 % higher.

The other source of error is the calculation of the input expressed as weight m^{-1} shoreline or weight m^{-2}. Assuming similar vegetation on both river-sides the catch on one side was multiplied by two. This may be regarded as erroneous, since wind mainly blowing in one direction will favour leaf-fall on one side and reduce the fall into the water on the other side. However, when determining the total input we are interested in both the leaf-fall *per se* into the water and the translocation of leaves from the ground to the water. The arrangement of the inner row of traps (fig 10) enabled the translocated leaves to be caught. Still, it is possible that my calculation over-estimates the leaf-fall, but this error must be relatively small.

Bray & Gorham (1964) have calculated a total tree litter fall to 350 m^{-2} yr^{-1} for the cold temperate zone of the earth. Considering that vegetation consists of several layers below the canopy and that all layers can contribute to litter input to streams, the given value should be increased. Different mechanisms of translocating the leaves, previously fallen to the ground, to the water surface will also tend to increase the figure given by Bray and Gorham. This is in good accordance with literature data for small streams. Vannote (1969) reported a range of leaf input of 200-800 g m^{-2} yr^{-1} for three streams in SE Pennsylvania, U.S. Cummins (1971) states 800 g m^{-2} yr^{-1} as

input of primarily leaf litter to a typical woodland stream. For a second-order stream Fisher & Likens (1973) estimated the leaf litter input to 356 g m^{-2} yr^{-1}. Dawson (1976) measured the litter fall to 240 g in an area with trees on only one bank, and to 466 g m^{-2} yr^{-1} in a wood, through which the stream flowed. These figures all concern small streams. The input values are more than one order of magnitude larger than those from the Rickleån.

The River Thames is a larger water-course. Here the leaf-fall is slightly more than 200 g m^{-2} at the bank and negligible at 13 m out (Mathew & Kowalczewski 1969). In the Rickleån the range of maximum autumnal leaf-fall close to the bank was 90-190 g m^{-2}. Also the values on an area basis agree relatively well: 23.2 g m^{-2} yr^{-1} for the Thames and 7-30 g m^{-2} for the Rickleån.

3.3 Littoral and submersed vegetation

The production of macrophytes can reach considerable quantities in slow-flowing sections of the Rickleån. The emergent vegetation and floating-leaved macrophytes are associated with the littoral zones and regulated by the strong seasonal regime of this zone. This is also the case for the *Carex* vegetation belonging to the eulittoral. The submersed plants, with *Ranunculus peltatus* as the dominating species, is certainly influenced by the seasonal flow regime of the river, but not to the extent of the vegetation associated with the littoral.

Equisetum fluviatile dominates the emergent species. No investigation of biomass and production has been performed except in a pilot-study in 1973. Quantitative samples were taken with a corer (174 cm^2) in a typical stand of *E. fluviatile*, approximately 50 m long and 4-6 m wide. The total biomass (incl roots) of *E. fluviatile* was 2.66 $\pm$ 0.59 kg ash-free dry weight m^{-2} (n=5) in August, and 3.07 $\pm$ 0.41 kg m^{-2} (n=3) in September 1973. The per cent of organic matter in the dry weight was 87.1 $\pm$ 1.7 for the stems and 65.7 $\pm$ 10.3 for the roots.

In June 1975 drifting LPOM were caught with a net (0.8 mm) every hour in three 24 h series. The composition of drifting materials, based on the dry weight of the different items, showed that *Equisetum* may sometimes be the major constituent of the drift (tab 9). However, on a yearly basis both the emergent and the submersed vegetation hold a small share of the total material transport. Also the nutritional value of *E. fluviatile* is low, e.g. the C/N ratio is relatively high. Thus, it is reasonable to assume that the impact of this material on the stream ecosystem is small, as is its contribution to the FPOM pool.

The rapids harbour thick carpets of water mosses, above all *Fontinalis antipyretica*. The species shows a relatively strong growth (Johnsson 1978). An evaluation of the role of the mosses in the Rickleån is made in the following section.

3.4 Transport and composition of LPOM

Method

Collection-bags were arranged against the current in the river at the field station. The mesh size of the net was 1.3 mm and the opening of the squared frame was very close to 0.1 m^2. The bag was operated for three hours daily, usually 9:00 - 12:00 a.m., except weekends; during high spring flood the operation time was one hour. The investigation period ranged from week 44, 1975 to week 50, 1976, with some shorter gaps. Two bags were arranged vertically upon each other, one collecting the surface and near-surface drift, and the other sampling only subsurface drift. The bag below the surface gave the most continuous series, and thus all calculations given refer to this bag.

After the exposition period the bags were emptied and sorted into the following vegetational groups according to origin: (1) *Equisetum*, (2) floating leaved and submersed plants, (3) water mosses, (4) green leaves, (5) brown-yellow leaves, (6) grass-like, especially *Carex* spp,

(7) twigs, coniferous needles and bark, (8) branches and large pieces of wood, and finally (9) remaining materials, i.e. small fragments of the other fractions, and especially the water mosses.

The different items were dried to 60°C for at least 24 hours, and weighed to 0.001 g. Branches and larger pieces of wood were dried for 2-4 days.

Values given are those of the transported material measured in grams per three hours (weekly means). Since no corrections have been made for the increased surface of the cross section due to high discharge the given figures can only be considered as a measure of the relative transport of the river.

Relative transport

The transport of LPOM has a very strong seasonal pattern (fig 11). The net-catches range from approximately 0.5 to 392 g. On 78 of totally 203 occasions the net-catches were <1.5 g, and on 143 occasions, which constitute 70 % of all samples, the catch was <3.5 g. On the other hand the catch was >21 g on 13 occasions during weeks 18-20, 1976, i.e. in connection with the ice-break. On a weight basis, it is very obvious that the bulk of the transport occurs during some few weeks of the spring flood. The transport on 13 occasions with >21 g per catch constitutes 71.8 % of the total catch from October 1975 to December 1976.

Composition

The different vegetational groups are compiled to larger entities as (a) water mosses and small fragments, mostly mosses, (b) woody tissues, and (c) remaining soft material (fig 12). There is an evident seasonal pattern determined by the discharge regime and the length of the vegetation period. Throughout the year the water mosses are the most important item. The dominance of water mosses in the drift is reversed at two distinct periods. The first period

embraces the weeks prior to the ice-break and some weeks after. Here twigs, branches and pieces of wood dominate up to 90 per cent. The second period is longer, approximately 10 weeks, and defined by the autumn leaf-fall.

Redistribution of leaves

Leaf-fall and leaf transport data have been compiled for 1975 and 1976 (fig 13). In 1975 the drift of leaves decreases immediately in connection with the ending of the leaf-fall period. This pattern was not evident in 1976. However, the high catches of LPOM after the leaf-fall period in 1976 can be explained. Week 45 in 1976 was the first period with air temperatures below 0°C. The water temperature fell immediately from 1 to 0°C, and ice was formed in the rapids. The following week was relatively warm, with an air temperature of +3 - +5°C, and slightly higher water temperature. All previously formed anchor ice melted, causing large quantities of bed-trapped leaves to be washed out. This sequence of temperature changes was repeated at the end of week 46 and the beginning of week 47, again resulting in a peak of drifting leaves.

Discussion

The water mosses provide the Rickleån with a base substrate for a variety of detrital processes participating in the total energy flow of the river. On a weight basis the woody tissues certainly would be important for the metabolism of the river, but as regards energy these tissues are probably of secondary importance, due to the long decomposition time of the wood.

Although the role of the autumn-shed leaves may not be so great on a yearly basis in comparatively large waters as the Rickleån, the leaves dominate the drift during a shorter period. In general it seems that the retention capacity of the river, especially the rapids, is great, but this is reversed by the effects of the anchor ice. Apparently in certain years the forming and melting of the

anchor ice will be an important mechanism for translocation and also fragmentation of the leaves. Both these processes increase the total loss of POM from the river ecosystem. The translocation will wash out leaves from the lower part of the Rickleån into the Gulf of Bothnia. Smaller fragments are more easily picked up by the turbulence of the water and transported longer distances than whole leaves. This will also increase the losses of the river ecosystem.

Fisher & Likens (1973) found no correlation between concentration of LPOM and discharge. They assumed that the LPOM transport followed an irregular mode, and that acceptable quantitative estimates are difficult to obtain by infrequent short-term monitoring. This phenomenon was also noticed in the Rickleån. Diel series (i.e. series running for 24 h) with net-catches differed very widely (tab 9). Fisher & Likens (op.cit.) explained the irregular mode of the LPOM transport with the establishment of "organic dams at the lower end of small pools". These dams suddenly release material which will appear as drift for shorter or longer periods. This mechanism cannot work in rivers like the Rickleån, but it is still possible that accumulations of larger particulate matter can be built up in the upper layer of the bed. These aggregations will also suddenly lose material to the drift pool.

In larger waters, however, the discharge is a useful parameter to predict the LPOM transport. The heavier components of the LPOM fractions as twigs, branches, pieces of wood can be taken to illustrate this in the Rickleån. The woody tissues seems to follow the general relationship between discharge and sediment transport established by workers in hydrology (Leopold et al. 1964, Morisawa 1968). The bulk of the transport thus occurs during short periods of high discharge. A slightly larger forest river, relatively close to the Rickleån, transported roughly 75 % of the total year transport (excl. the bed load) during 2 months (Nilsson 1972). In the Rickleån the woody fraction of the LPOM drift fits this concept well.

4. TURN-OVER OF DETRITUS

4.1 Introduction

LPOM of various origins are mechanically broken down by the force of the turbulent water, through the feeding activity of the bottom invertebrates, and by microbial activity. All these processes promote fragmentation and, as a consequence, a large pool of FPOM is built up. This is mainly due to in-stream processes (Cummins 1975). The FPOM will be further colonized by microorganisms and incorporated into different processing sites. Three main sites are recognized in the Rickleån and they will be discussed in section 4.3.

The decomposition, or the turn-over of detritus will be reviewed from two separate investigations, both including more elements than decomposition of detrital matter. The first study (section 4.2) deals with the fragmentation and the decomposition rate of LPOM, represented by leaves. The other study (section 4.3) is based on measurements of the community respiration of FPOM and periphyton attached to the organic layer around stones.

4.2 Fragmentation and decomposition of leaves

Methods

The fragmentation and decomposition rate of leaves (*Populus tremula* L. and *Alnus incana* (L.)) was measured by the weight loss of leaf-packs (Petersen & Cummins 1974) in the autumn 1974. Two sets of different leaf-packs were used. *Populus*-packs of 5 g dry weight (the petioles were removed) were tied together by nylon threads and placed in front of exposed stones in wooden channels continuously receiving river water (Karlström 1976b). The second set consisted of both *Populus*- and *Alnus*-packs of 10 g dry weight (the petioles were left), pressed on nails hammered into pieces of wood. This set was placed out in the river and exposed to a considerable turbulence due to heavy autumnal rain that year. Both old leaves, shed the year before, and newly shed leaves were used in separate packs in the two experimental series.

The first set of leaf-packs (5 g) was exposed during August and September while the water temperature fell from 15 to 8.5°C. The second set (10 g) was exposed from late September to mid November. During this period the water temperature fell from 9.5 to around 0°C. Beside differences in temperature and amount of leaves the 10 g packs were exposed to more turbulence than the 5 g packs.

Result

New leaves are broken down at a rate of 0.95 - 1.23 per cent day^{-1}, measured during different periods up to 35 days (tab 10). The older leaves show a considerably lower fragmentation and decomposition rate, 0.45 - 0.71 per cent day^{-1} due to their pre-leached and more refractory condition.

Newly shed *Populus tremula* leaves differ only slightly, while the older leaves show a greater difference. This is to be expected since the older leaves vary more in the state of decomposition.

10 g leaf-packs were also placed in a small tributary, the Trysjöbäcken (fig 14). The water had a high humic content and was rather acid; pH around 5. Here the break-down rate was considerably lower. After an exposition period of 35 days the loss rate was 0.60 per cent day^{-1}, compared to 0.95 - 1.02 for the Rickleån. The conditions of turbulence and temperature were roughly the same in the tributary and in the channels.

Discussion

Different leaf species have different decomposition rates and, thus, it may be more informative to characterize leaf species as "slow", "medium" or "fast" (Petersen & Cummins 1974). Within the same species the decomposition rate is mainly regulated by temperature (Iversen 1975, Suberkopp et al. 1975). The pattern of the decay curve varies from an exponential decay model for materials

entering a stream in the summer or the early autumn to a more linear function for materials of the late autumn or winter. Consequently many stream ecosystems are furnished with a rather complex process of turning terrestrial organic matter into the different detrital components.

The material from the Rickleån was exposed up to 8 weeks. A comparable, short term study by Suberkopp et al. (1975), exposing leaf-packs for 4 weeks, showed roughly the same loss rate (tab 11). In a long term study, Mathews & Kowalczewski (1969) found loss rates of 0.52 % day^{-1} calculated over 5 months and 0.40 % day^{-1} over 8 months. After 9 months Suberkopp et al. (1975) estimated the loss rate to 0.4 % day^{-1}. With pre-leached leaf-discs Iversen (1973) calculated the daily loss per cent to 0.25 over one year. Petersen & Cummins (1974) state a loss rate of 0.5 - 2.0 for a variety of leaf species and seasons.

Evidence has accumulated that changes in both minor and major constituents of the water can effect the decomposition rate (Hynes & Kaushik 1969, Egglishaw 1972, Hynes 1975). The Rickleån is poor in nutrients, especially above Robertsfors, and a hypothesis was proposed that the addition of nitrate would increase the decomposition rate. This was also demonstrated in a field experiment (Karlström 1976b).

What is the fate of leaves entering streams? How long will it take before the leaves are decomposed more or less completely? Taking the time for 90 per cent weight loss of the leaves as an index of disappearance time most leaf species will reach this level within or in about one year (tab 13). Slow species or species in "unfavourable" waters will take more than one year. However, it should also be stressed that the leaf-packs do not fully reflect the weight loss in nature, although leaf-packs must be preferred to, for example, net bags. In the Rickleån leaf accumulations are rarely noticed in front of stones for any longer periods. Thus, a free, movable leaf will experience more turbulence and more physical abrasion than

leaf-packs, and hence account for a larger percentage loss. It is true that leaves may fasten in the river bed and thus keep away from the turbulent water, but on the other hand, autumn floods and anchor ice cause a considerable redistribution of the leaves. Therefore, it seems reasonable to conclude that the leaf-pack technique is a conservative estimator of the true rate of leaf degradation.

4.3 Structure and function of the organic layer

Introduction

This section deals with the structure and the function of the organic layer covering the stone surface in the Rickleån. The aim of the study was to initiate an investigation into the role of the organic layer in the detrital metabolism of the river. Investigations were also carried out concerning other detrital processing sites, such as the upper part of the hyporheic habitat (R.C. Petersen, 1974) and the water-mosses (T. Johnsson 1974-76).

The organic layer around stones will be discussed from three aspects: Total amount of attached material, structural elements, and community respiration.

Finally, the available information on the community respiration is compiled for the Rickleån and the magnitude of the maximum turn-over rate is discussed.

Materials and methods

From June to September 1975 stones taken from the rapids were mechanically brushed in a standardized manner (rotating the stone and brushing it for up to 1 min). The stones were brushed separately with an ordinary paint-brush and with a wire brush. The material removed was suspended by violent air-bubbling in 0.5-1.0 l of deionized water and subsamples of usually 10-20 % of the total volume were taken out. The subsampling procedure was tested once and found very accurate. The loss on ignition (500^{o}C, 3 h) was determined by ashing the filter retenate

from two subsamples, and weighed to 0.1 mg.

The amount of organic matter was related to (1) the volume, (2) the projected surface (P-surface), i.e. maximum length X maximum width, and (3) the total surface of the stones (T-surface). The latter was done in a rather laborious manner by transferring a suitable number of sub-surface via a transparent plastic film to a paper of known weight in relation to its surface. The total surface of a stone was calculated by adding the weight of all sub-surfaces.

The composition of the organic layer was examined with a light transmission microscope and a scanning electron microscope. Samples of material brushed off in 1975 were mounted with glycerine gelatine on slides or filtrated through Millepore filters (0.45 um) which were made transparent by immersion oil. The slides were later studied in a light microscope.

From the summer 1976 to the winter 1977 slides, pieces of plastic film and small stones, roughly 2-5 cm in length, were fixed in glutaraldehyde, and treated mainly according to Paerl & Shimp (1973). The dehydration worked out well and the organic layer was left apparently intact. The material was examined in a scanning microscope (JEOL JSM-P15). Stones of approximately first-size were sampled from the Rickleån during the summer and autumn 1975. They were transferred to cylindrical respiration chambers of plexiglass, which were filled with river water. During operation, the chambers were kept submersed in river water, which was continuously renewed. The temperature difference between the river water and the water within the chambers was small, 1-2^{o}C. Two types of chambers have been used. The first one (volume:3.5 dm^{3}) was constructed in 1974 by R.C. Petersen (Stroud Water Research Center, Penn, USA). and in 1975 the second, smaller chamber (volume 1.15 dm^{3}) was built by the present author. The chambers agree largely with already described types, e.g. Thomas & O'Connel (1966), Hansman et al. (1971). Holes on the top of the chambers permit oxygen electrodes to be

inserted after which they are sealed tightly. A continuously operating recorder is connected to the arrangement. The electrodes (Yellow Spring Instruments, USA) are equipped with vibrators, thus causing the water to circulate inside the chambers. The water velocity in the chambers was measured to 0.2-0.5 m s^{-1}, with the larger chamber at the lower and the smaller chamber at the higher range.

Throughout the year the river water is saturated, or close to saturation, with dissolved oxygen. To resemble this condition the respiration rate is defined as the consumption during the time until approximately 90 % saturation level is reached. Since the fall of oxygen concentration in the chamber follows a curve-linear function, the choice of a lower saturation level would give a lower consumption rate. Another delimitation is also necessary since during all respiration measurements a similar pattern of a fast, initial consumption was noticed. This can be interpreted as a stress response from the micro-organisms before adapting to the environmental conditions in the chamber, e.g. hyper-activity, or a response of the microbial community to metabolites released from damaged cells in connection with sampling. Consequently, the first 10-15 minutes of measurements are not included in the present calculation.

Total amount of organic material

The stones in the Rickleån are coated with a considerable amount of organic material. The total yield of this material is dependent on the extraction method. Mechanical treatment has to be very intensive, and even five rounds of wire-brushing, material remains attached to the stone (fig 15).

The total material shows a minor variation, although it represents stones sampled on different occasions, in different localities, depths and water velocities (tab 13). In relation to the projected surface the confidence limits

($p<0.05$) of the extracted amount are 30-40 mg dm^{-2} (35 mg dm^{-2} as a mean) for combined brushings. This gives a ratio of 1:3 between soft and combined brushing, where the combined brushing here includes only one round of wire-brushing. The first round was shown to give approximately 50 % of the amount gained by consecutive wire-brushings (fig 15). Using this approximation, the relation between soft brushing only and the total extractable amount is 1:5.

Studying the colonization process on glass slides, Madsen (1972) advanced a qualitative model of the building up of the organic layer. The model recognized an initial phase where diatoms, fungi and bacteria colonized the surface and incorporated dissolved organic matter. Detrital particles were trapped on this initial layer forming a new outer layer. This concept of several layers is supported by the results of the present study.

In colonization experiments two sets of well-brushed stones were exposed for up to one month. At different intervals 1-3 stones were sampled and the amount of accumulated material was determined by soft brushing (fig 16). A fast, initial building up occurred after 3-5 days, followed by a relatively long period with a more or less stable amount of colonized materials. After a month the accumulated amount reached around 30 mg dm^{-2}. Both series showed a similar pattern. The exposure time was too short to demonstrate whether the accumulated amount would stabilize at a steady state level.

In 1975 an experiment with light and dark exposures of well-brushed stones was set up. The stones exposed to light had a significantly higher amount of organic matter at the end of the experiment (tab 14). This was due to the reduced development of the epiphyton, mainly diatoms, under dark exposure. The effect of the diatoms can manifest itself in two ways, partly by directly increasing the total amount of organic material and partly by contributing to a network, which enables more material to get trapped (Madsen 1972).

Since the diatom development is subjected to seasonal variation it may be assumed that the organic layer also experiences seasonal variations.

Stones sampled at the beginning of the summer (tab 15) show lower amounts of organic matter than the mean value for the whole material, which was sampled from June to September (tab 13). The peak of the algal cell drift was reached approximately three weeks after the first sampling occasion in 1975 (fig 23). However, it has been claimed that there is no correlation between drift and benthic production of algae during the spring (Müller-Haeckel 1976).

Several factors determine the amount of organic material attached to the stones (tab 16). In general the effect of each factor is hardly difficult to predict, but the combination of several factors at different intensities may lead to very complex situations. Schematically, four periods can be distinguished in the development of the organic layer:

1) During mid and late winter, with a low particulate load of the river water and, assuming a largely temperature dependent function, low decomposition rate.

2) During the spring flood, a high particulate load and very unstable conditions in the stream bed due to heavy turbulence; relatively low decomposition rate.

3) During the summer and autumn, with average particulate load, low turbulence, maximum benthic primary production; high decomposition rate.

4) During the autumn and the early part of the winter, usually with high particulate load due to flood conditions, increasing turbulence in the bed and formation of anchor ice; low decomposition rate.

Based on these conditions, the development of the organic layer on the stones would be expected at a minimum level

during the winter, spring and a period after the spring flood. Maximum development of the organic layer would take place during summer and autumn. The results presented provide some support for this hypothesis.

Structure of the organic layer

On examination of the slides in a light microscope the most abundant items were noted, i.e. algal cells, leaf fragments of water mosses, fragments of macrophyte tissues, mineral particles, animal remain, fungal tissues, large unidentified particles (mostly sphere-shaped, 25-50 µm, but also thread-shaped) and a large number of small unidentified particles. Unidentified large and small particles totally dominated the samples.

There was a distinct difference between the material derived from soft or hard (wire) brushings. The soft brushing apparently removed all large algal cells, the major portion of medium and small algal cells, as well as large detrital fragments, more or less sphere-shaped (>25 µm). The particle size distribution can be characterized by a modal value in the range 25-60 µm. Thread-shaped particles were often also observed. Aggregates of an approximate size of 80-126 µm were found rather frequently. These aggregates were composed of small particles, often with 1-5 algal cells per aggregate.

The fraction obtained with the wire-brush contained very few algal cells, often dark detrital particles, most often in the size range 2-20 µm. Thread-shaped fragments, 50-20 µm long, or the aggregates described above were hardly ever found on the slides. Thus, the particle size distribution had a lower modal value compared with the distribution from the soft-brushed material. Of course, to a certain extent the size distribution in the result of the mechanical grinding from the wire-brush.

The results of the scanning microscopy are mainly derived from three series: 1) slides exposed 2.5 months under

darkness in experimental channels continuously receiving river water, sampled at the end of September, 2) pieces of plastic film exposed 3.5 months in channels under natural light conditions, sampled at the end of October, and 3) small stones taken from the Rickleån at the Isakfäboda rapids.

The organic layer of the stone surface was found to be a very complex, multistoreyed structure (fig 17, A). A layer consisting of crustaceous algae, diatoms and fungi can be seen at the bottom. Diatoms and fungal bodies are frequently embedded in a smooth substance, possibly of mucoid origin and excreted by bacteria and algae (Allen 1971). This substance often forms a matrix which is overgrown by fungi. Without sufficient primary production the organic layer would not be able to develop several storeys. This can be seen from material kept under dark, experimental conditions (fig 17, D). Despite being completely covered by a mucoid layer the surface still manages to trap material drifting with the water, e.g. pieces of diatom frustuels, but is not able to erect several storeys. Both diatoms and noticeable amounts of fungi are absent. The fungal mycelium or hyphae and the mucilage-stalks of some diatom species thus function as structural compounds in a network which can extend itself by trapping FPOM drifting with the water. The lack diatoms may perhaps explain the absence of fungi, since the excretion of DOM from the diatoms is one important feature of the chemoorganotrophic community (Allen 1971).

Stimulated by this concept, Allanson (1973) published a series of scanning electron micrographs demonstrating the aufwuchs community on submersed macrophytes. One of the major prerequisites of this system is the secretion of DOM from the macrophytes. However, the aufwuchs community on the stones is able to establish a multistoreyed complex without the immediate support of secretions from the substrate. There are several reasons for this success of the epilithic community, but obviously the continuous supply of drifting FPOM will be a substantial factor.

The recognition in the early 1960's of woodland streams as strongly heterotrophic systems (e.g. Hynes 1963, Ross 1963) focused attention on the leaf import. Both Hyphomycetes and Actinomycetes were reported to be associated with leaves in streams (for references, see Jones 1974, Ingold 1975, Willoughby 1976). Other fungal groups, as yeast, have also been isolated from rivers (Spencer et al. 1974). Studying stream-exposed slides, Madsen (1972) found an abundance of small spherical bodies and assumed them to be yeast cells.

The Rickleån community and that of Allanson (op. cit.) differ in one important aspect, namely the role of the fungi. In the Rickleån fungi and actinomycetes apparently have an active role. The slightly acid, humic water of the taiga lakes or rivers offer perhaps a competitive advantage to certain fungi over bacteria. Willoughby (1974) has also suggested that fungi and actinomycetes may well be the more important microorganisms under aerobic conditions in decomposition of plant material.

Community respiration

Benthic respiration in relation to the projected surface of the stones ranges from 0.17 to 1.15 g O_2 $m^{-2}d^{-1}$ in the interval 11-20°C (fig. 18). The measured stones were sampled on different occasions and in different localities, and represent a wide range of environmental conditions. There was no intention to outline a mathematical relationship between respiration rate and temperature, but it has been shown that community respiration is temperature-dependent (see also, for example Hargrave 1969).

There is strong evidence that the water velocity determines to a certain extent the respiration rate of different benthic substrates. This has been demonstrated by Carey (1967) and Martin & Bella (1971). However, the effect of water velocity on community respiration may be limited to certain critical velocities or oxygen

saturation levels (Hargrave 1969). In the Rickleån material, little or no effect of the water velocity was found in the interval 0.2-0.5 m s^{-1}, when respiration chambers with different volumes were used (tab. 17). According to the views of Fenchel (1972) the absolute respiration values in relation to weight (soft brushing) were very high, or even too high. One explanation is that the soft brushing alone did not remove all the respiring biomass. However, Odum & de la Crus (1967) state a high respiration value of fine particulate detritus, 0.258 g O_2 $g^{-1}d^{-1}$.

A comparison of the Rickleån data on community respiration with literature data demonstrates that the values are of about the same order of magnitude (tab. 18). This may be explained by the hypothesis put forward by Hargrave (1969) that different environmental factors appear to be of secondary importance to temperature in effecting oxygen uptake. The temperature regulation would then operate through the diffusion of oxygen. When we realize that the organic layer actually is a multistoreyed structure it is reasonable to assume the existence of relatively strong oxygen diffusion gradients even in well-oxygenated running waters.

General discussion

The organic layer of the stones harbours an abundant fauna of protozoans and micro-metazoans, which can be easily observed when live in fresh samples. Probably these groups do not graze upon the particulate material per se, but more on the microbes colonizing it. Acarids and nematodes have been reported to graze upon fungal mycelia (Gessner et al. 1972). Nematodes have been observed on stones in the Rickleån, but they were not strikingly abundant. Small chironomids may sometimes be very abundant and in such cases the organic layer must be dramatically moulded. Benthic macro-invertebrates, finally, seem to have a minor overall role in the turnover of the organic layer due to their aggregated distribution leaving much of the bed substrate more or less free of grazing. Moreover, the

major portion of the macro-invertebrates inhabiting the rapids are, trophically, collecters and not grazers (sensu Cummins et al. 1973).

Using the different investigations in the Rickleån during 1974-76 a tentative estimate of the total benthic community respiration can be compiled (tab. 19). The given range is probably wider since late autumn measurements did not embrace the same temperature interval. But it is a minor objection. Community respiration includes both autotrophs and heterotrophs. The bulk of the *Fontinalis* community respiration can be attributed to the moss itself, and not to the mainly heterotrophic aufwuchs. Thus, it would be an overestimation to equate the community respiration with the activity of the heterotrophes, i.e. approximately the detrital processing capacity. On the other hand, the community respiration of the hyporheic habitat is estimated by measurement of the top 4 cm, which is certainly an underestimation. Therefore, the total community respiration can be regarded as a tentative estimate of the maximum decomposition rate of the rapids.

5 LOAD AND TRANSPORT OF DOM AND FPOM

5.1 DOM

Methods and sampling

Water samples for the determination of DOM were taken approximately twice a month around 4 p.m. during 1973-76 at the field station. The samples were transported to Umeå and kept overnight at 2°C and processed on the following morning. The amounts of DOM were determined by wet oxidation with potassium dichromate mainly according to Standard Methods (1965). Open air-coolers were used (TeKippe & Zehnfennig 1971). Diel variation was also studied during several day and night series in 1973-75 from two sampling points (above Robertsfors and the field station). During these series the analyses were performed immediately or within 30 min at the field

station.

It should be noted that in the present context DOM also includes a part of the colloidal fraction of the organic material.

On a sampling tour on December 5, 1974 optical density and the humic content were determined at 7 stations in the lower part of the drainage basin. The humic content was analyzed with a fluorescence method (Almgren et al. 1975) by the Department of Analytical Chemistry, University of Gothenburg. The fluorescence method was calibrated against a humic standard derived from the River Göta älv in southern Sweden. The intensity maximum of the samples from the River Rickleån drainage basin deviated somewhat from the standard, but the deviation was small and the given amounts are acceptable approximations.

General characteristics

The Rickleån carries considerable amounts of dissolved organic matter during the year. The maximum range is nearly one order of magnitude, 15-110 mg O_2 l^{-1}, which refers to the diurnal variation. The seasonal variation is smaller, 20-70 mg O_2 l^{-1} (fig. 19); maximum values occurred during the summer 1974 and minimum values are found during the summer in some years. No obvious seasonal pattern is discernable.

DOM constituted the bulk of the total organic matter in unfiltrated samples. The ratio of DOM to FPOM varied between 7 and 39 during the years investigated. A high particulate load, resulting in a low ratio, occurred only during short periods of high discharge and heavy rains. However, heavy rains, as in the autumn 1974, can also result in high DOM concentrations and thus increase the ratio. Modal values are found in the range of 17 to 25.

Diurnal variation

The diurnal variations can be associated with heavy rains, as July 15-16, 1974 (fig. 20), when the average level was higher than normal. A marked diel change can be observed (fig. 21) during periods with no or negligible precipitation, stable meteorological condition in general and no detectable change in water level at the field station. During such periods the average level is low. The diel series demonstrate that parallel fluctuations can occur at the two stations. This parallelism can apparently be induced by rains covering at least the distance between the two stations. Diel series which are not synchronized also occur, e.g. on July 28-29, 1975. They may be explained by a pulse from the upper part of the river where there will be a time lag before the pulse reaches the mounth.

Humic content

A major portion of the DOM in the Rickleån can be characterized as humic compounds. When the DOM reaches the lower part of the Rickleån drainage basin it has been transported over a long distance, and a certain amount has already been removed from the water. The optical density as well as the humic content decreases downstream (fig 22). A dramatic decrease seems to take place as the water moves through Lake Bygdeträsket. It is wellknown that lakes may act as clearance basins within a drainage basin.

From the absorption spectra of the standard, coefficients can be derived to calculate a theoretical absorbance. The ratio between this and the measured absorbance shows how much of the absorbance is due to humic substances. The stations in Lake Bygdeträsket and in the Rickleån have a ratio of 0.4, while the inlets to the lake have a ratio of 0.3. This implies that there are other substances in the water that also absorb the emitted wavelength. Probably the composition of the DOM is also altered to

some extent due to flocculation and sedimentation as the material is transported through the lake.

General discussion

There are reasons to expect a seasonal variation of the DOM content. During winter a substantial flocculation occurs in the river. This was found repeatedly during 1973-75 when stones were brushed in order to sample the benthic invertebrates; the stones were covered by soft, very dark flocculates. During the summer it is reasonable to expect a reduction of the humic content due to photo-oxidation (Gjessing & Gjerdahl 1970). However, a seasonal pattern has not been noticed (fig. 19). One explanation for this is that the diurnal variation of the DOM content is much larger than the seasonal variation. This implies that a small long-term variation may be covered by relatively large short-term variations when different sampling intervals have been used.

Evidently, the concentration of DOM is largely regulated by meteorological and hydrological vectors. On a seasonal base no correlation exists between discharge and DOM in the Rickleån. However, during short periods, e.g. the summer-autumn 1974 (fig. 19) or during some diurnal series (fig. 20), such a correlation may be established. Discharge and concentration of DOM are usually correlated in small streams (Fisher & Likens 1973, McDowell & Fisher 1976), though the correlation sometimes may be weak. Actually, discharge alone is not a satisfactory means of predicting DOM concentrations, since some streams respond very little to rainfall, while others respond rapidly. The effect of heavy rains will vary depending on several factors, e.g. the depth of the water table, velocity of subsurface seepage and channel enlargement (Carson & Sutton 1971). Recent hydrological concepts (see Hynes 1975 for references) stress that the surface runoff may not be the dominant feature. Rather, it is the subsurface water, replaced by the penetrating surface water, that enters the channel, or that a lateral

enlargement of the channel system takes place. These pathways may postpone the effects of rains and alter the composition of outflowing water.

Several workers (Cummins et al. 1972, Wetzel & Manny 1972, Hynes et al. 1974) have demonstrated that leaf leachate is utilized very rapidly by the microorganisms in the stream. Especially in small streams this category of DOM can contribute substantially to heterotrophic growth. McDowell & Fischer (1976) reported that 77 % of the total leachate input was assimilated along a section of 1260 m. But not all of the leachate will be assimilated rapidly. Wetzel & Manny (1972) demonstrated that the leachate can be separated into a labile and a refractory fraction with biological half lives of 2 and 80 days respectively.

This leads to the conclusion that most labile compounds are utilized so rapidly that they do not reach the headwaters of the drainage basins. Except for small streams, a large portion of the plant litter will be pre-leached, i.e. devoided of labile DOM, before it reaches a water course. Therefore it is reasonable to assume that most of the measured DOM in the Rickleån is refractory, and that its impact in promoting heterotrophic growth is small.

5.2 FPOM

Methods and sampling

The organic part of the seston load of the river water was measured during 1974-76 by filtering 0.75-2.0 l, mostly 1.0-1.5 l, of water through precombusted glass fibre filters (Whatman GF/C). Before filtration the water samples were screened through a net of 250 µm mesh size. The amount of organic seston was determined as loss on ignition (roughly during 24 h at 65°C and during 3 h at 500°C) and weighed to 0.1 mg.

Water samples were taken daily, except weekends, from the

old fish trap out in the river where the current is swift and the water column well mixed. On each sampling occasion around 4 p.m. a 10 l bucket was filled and as a rule two subsamples were filtrated. The glass fibre filters do not have a defined pore size, but the manufacturer states the pore size of the Whatman GF/C to be approximately 1 µm. Conventionally, 0.5 µm pore size is used to separate particulate from dissolved matter. This implies that initially when only small amounts of water have been passed through the glass fiber filter the retention of the particulate fraction is not complete. This was also demonstrated when the FPOM concentration in the Rickleån was extremely low. Filtering only 1 l gave a FPOM value of 0.07 as an average, while 2 l subsamples gave 0.23 mg l^{-1} (table 20). When further amounts of water are passed through the filter, it gets clogged and hence the retention capacity increases considerably. Actually, this is one implication of using a depth-filter such as the Whatman type. Therefore the sampling volume has been changed during the year in response to the changing FPOM load.

The general FPOM levels are low in the river, so small differences in the treatment steps will cause relatively large statistical variations. On a number of occasions during 1975 5 subsamples were taken (table 21). The coefficient of variation of the mean ranged from 2 to 17 % with an average of 11 %, which is a comparatively small and acceptable level of variation.

Different FPOM-fractions were measured in 1976 by screening 20-100 l river water samples at the field station through nets of the following mesh-sizes: 25, 85 and 450 µm. Four different fractions were obtained by combining the net-catches with filtering, 1-25, 25-85, 85-450 and >450 µm. The amount of organic matter was determined as loss on ignition and weighed to 0.1 mg. When a volume of 100 l was filtrated the seston content could be determined down to 0.001 mg l^{-1}.

General characteristics

The total concentration of FPOM varies throughout the year from 0.2 to 5.7 mg l^{-1} as the extreme range and with a modal range of 0.5-3.5 mg l^{-1} (fig. 23). Larger increases are connected with the spring flood in April-May and to a lesser extent with autumn floods. Lowest values are found in February to April, prior to the ice break. Except from these periods the FPOM level fluctuates around a base-line of approximately 1 mg l^{-1}. Day to day fluctuations occur, but do not seem to be an important feature. On the other hand, oscillations of the FPOM level covering shorter periods, e.g. 3-5 days, are rather common. Intermingled between these periods of transitional concentration values are periods with stable values over several days or periods with only slight changes.

Particle size distribution

During the annual cycle particles <25 µm constitute 43-94 % of the total FPOM (tab. 22). However, most frequently the finest fraction makes up 85-94 %, which certainly indicates a very skewed distribution towards the finer fractions.

On August 3, 1976 the diameter of particles <15 µm in the seston were counted at a magnification of 750 in a set of samples from the field station. All samples showed the same pattern with a strongly skewed frequency distribution regarding the particle diameter (fig. 24). The distribution model may roughly be described as a negative exponential function. Besides a large amount of small detrital particles in the approximate size of 1.5-2 µm, there was a very high number of small flagellates. The flagellates constituted 50-60 % of the finest fraction measured. Of course, the high abundance is subjected to strong seasonal variations.

Based on the estimated particle diameter and assuming the

particles to be spheres, the volume for each particle size group was calculated and plotted (fig. 24). Large particles are not necessarily sphere-shaped and thus the calculation will somewhat overestimate the importance of the relatively larger particles. With this constraint in mind it seems that the bulk of the FPOM on a volume or weight basis will be found in the range of 10-25 µm.

Hynes et al. (1974) investigated the particles' size distribution during a period of 4 months and found 4 peaks in the range of 10.6-26.7 µm. Their data also show how highly variable the FPOM concentration can be both over short periods of time and seasons.

Seki et al. (1969) investigated a small river, Nanaimo River, and reported that the mode of the particle size distribution was 20 µm in the summer. Winter sampling gave considerably smaller particles, but these were dominated by inorganic materials. For 16 U.S. streams and rivers Sedell et al. (1978) reported that the transported FPOM had a mean particle diameter between 5 and 12 µm. Apparently, an over-all feature of the FPOM transport is the total dominance of small particles, i.e. <25 µm in diameter.

During high discharge particles >25 µm increase both in concentration and in relative importance of the total FPOM (fig. 25). In 1977 a maximum value of 2.49 mg l^{-1} is recorded, which makes up 57 % of the total FPOM (tab. 22). The high values level off within a couple of weeks and then particles >25 µm constitute 10-15 % of the total transport.

The 4 different size fractions behave very differently during the year. The fraction 25-85 µm is most variable with a ratio of approximately 140 between maximum and minimum concentrations (tab. 23). The larger fractions have smaller ratios. To conclude, the bulk of the POM transport is made up of particles <25 µm, and especially in the range 10-25 µm, but during high discharge also larger particles, e.g. 25-85 µm, will contribute to the

POM load. Particles >85 µm are of no real importance in terms of load and transport.

Short-term variations

On three occasions samples for total FPOM analysis were taken during at least one day and one night (tab. 24). Short-term variations occurred, but the differences were small, and no recurring pattern of variations was discernable. Part of the variation can also be attributed to sampling and treatment errors.

It has been shown by several workers (Blum 1954, Müller-Haeckel 1967) that the algal drift in streams experiences a pattern of diel variation due to metabolic activities induced by the light. This diel variation also seems to embrace a large portion of the total aufwuchs community (incl. faunal components) in streams. It implies that all living components - frequently drifting - and the materials they generate (e.g. fecal pellets) will experience a pattern of diel variation depending on the season. However, on a weight or volume basis the living component only comprises a smaller part of the total FPOM transport, and hence it was assumed that no diel pattern for FPOM would be discerned for the Rickleån.

Fisher & Likens (1973) reported a ninefold increase in FPOM concentration between two consecutive samples due to a light shower. Dramatic changes in concentrations overnight were also reported by Hynes et al. (1974) due to summer rainstorms. Also light rain may considerably alter FPOM levels in small streams by washing particulate matter from the vegetation canopy. It can be assumed that this mechanism must have little influence on larger streams, like the Rickleån.

Variations along the river

On several occasions samples for determination of FPOM were taken simultaneously or within a few hours at the field station and at a station above Robertsfors (tab 24 and 25). There are occasions when the levels are equal or

even higher upstream, but the dominant trend is that the concentration of FPOM is higher at the field station.

It is reasonable to assume differences in the FPOM load between the rapids due to different retention indices, e.g. slope, substrate or distribution or water mosses. To evaluate the effect of these factors samples were taken from 5 rapids along the river on the same day in each month. The results (tab. 26), summarizing three years, also indicate that the station downstream Robertsfors, and especially Gamm strömmen, have the highest FPOM concentration. Apparently differences exist between the downstream rapids. In 1974, for example, the value from Laxbacken is even lower than the stations upstream of Robertsfors.

The results indicate higher concentrations downstream, but the differences are small.

General discussion

The bottom structure seems to be decisive for the amount of organic matter that can be stored in the stream bed. The extreme bottom types can be designated as the uni-layered and the multi-layered, respectively (fig. 26). The "trapping capacity" of LPOM is most developed in the multi-layered type. However, depending on several factors, sandy stream bottoms can hold considerable quantities of organic matter (Nelson & Scott 1962). The coarse materials, trapped in the bottom, will successively be processed into finer categories and thus containing a large reservoir of FPOM, which supplies the stream water passing above the bottom with FPOM. It is reasonable to assume two supply patterns; 1) a constant release and 2) strong pulses in response to periods of high turbulence, or discharge.

It is well recognized by hydrological workers that discharge and suspended load are fairly correlated (Leopold et al. 1964, Morisawa 1968). The organic part of the total suspended load consists mainly of FPOM,

which are more easily moved by the water and transported longer distances before settling than the inorganic particles. Still it is possible to predict FPOM concentrations from the discharge, since, probably, discharge is the main factor regulating the FPOM load in running waters (Nelson & Scott 1962, Maciolek 1966).

The stream transports the bulk of the total year transport of FPOM during a short period of time in connection with floods. For the remaining parts of the year the concentration level fluctuates rather moderately. Investigating the Öre river, not far from the Rickleån, Nilsson (1972) reported that this forest river transported 70-80 % of the total year transport of FPOM in two months. Of course, this pattern will be altered as the regulation degree of the water system increases. Thus, the concentration of FPOM can be reasonably predicted by the discharge. The prediction will be more accurate if the discharge peak can be separated into the ascending and the descending phase.

In the Rickleån the fluctuations of FPOM concentration are rather small, if only the normal range is considered; 0.5-3.5 mg l^{-1}, i.e. 1:7. However, if the extreme values from 1974-77 are included the ratio is 1:29. The corresponding ratio for the Thames is reported to be 1:16 (Berrie 1972). Nelson & Scott (1962) gave a very wide range for the Middle Ocone River with a ratio of 1:150.

What are the main factors determining the levels of FPOM content in a stream? In table 27 a number of streams with varying amounts of information on the FPOM load have been compiled. This material seems to allow some general conclusions.

Very productive streams generally have a high amount of sestonic FPOM, e.g. English chalk-streams (Ladle et al. 1972). The situation is apparently the same for mildly polluted streams, as part of the Thames. This is in sharp contrast to clear mountain streams such as the Convict Creek and, to a lesser extent, the inlet to Lake Ö. Heimdalsvann.

Small, strongly heterotrophic streams, which are more or less completely covered by a vegetation canopy, could be assumed to carry a considerable load of FPOM. Surveying the literature it seems that this is not a general feature. On the contrary, some of the very small streams have low concentrations, e.g. Sugebaeck, Bear Brook and Roaring Brook. Catahoula River is also a small stream in a heavily forested watershed, but here the FPOM concentration is high. However, the investigation embraced only 6 sampling occasions from February to August, so the yearly range is probably wider. Larger, unpolluted rivers (Middle Ocone River, the Öre River, the Rickleån) have moderate to high concentrations, and considerably higher than some of the smaller order streams previously discussed.

Occasionally, streams may hold a very high FPOM load; 90 mg l^{-1} in the Middle Ocone River, 60 mg l^{-1} in some Canadian streams, and probably similar amounts in some of the larger English chalk-streams (Dr Ian Farr, pers. comm.). These peak concentrations are found during spates and may last only for a few hours, and during extremely high discharge with recurrence intervals of approximately >10 years. Therefore most stream investigations are not able to provide information of the true range of the FPOM load in running waters. De la Cruz & Post (1977) stated that the range of the particulate organic load in most rivers was 1-10 mg l^{-1}. Obviously, this is a simplification. Perhaps it would be more useful to give a statement about the range of the mean or the mode of FPOM load; the range 0.2-5 mg l^{-1} seems to cover most of the streams investigated.

5.3 FPOM in relation to chlorophyll *a*

Water samples (n = 3; exceptionally 1-2 or 4) for chlorophyll determinations were taken around 4 p.m. about twice a month during 1974-76, and preserved with $MgCO_3$. 0.7-3.0 l were filtrated through a Whatman GF/C glass fiber filter. Extraction was done in acetone and the

grinded samples were stored cold and dark for 12-16 hours, mainly according to the manual of Tolstoy (1969).

Chlorophyll a concentration varies from 0.2 to 3.5 mg m^{-3}, with the lowest values during December-April (fig. 23). Highest peak values are found during a relatively short period; roughly the first two weeks in July. During the autumn the concentration levels off slowly and does not go below 1 mg m^{-3} until the end of October. In 1975 a slight autumn peak was reached in September. This could also be true for the previous year, but more covering data are lacking.

During the three years the maximum peak value increased slightly, from 3.1 to 3.5 mg m^{-3}. However, it is not possible to state whether this measured increase actually was an increase due to the length of the sampling intervals and/or to a lesser extent, to analytical errors.

Chlorophyll a content seems to be an acceptable estimator of algal cell number, and consequently of algal biomass in the Rickleån. A good, linear correlation was found between total algal cell number and chlorophyll a content; r = 0.85, n = 18 (Karlström & Backlund 1977). Such a correlation has also been demonstrated for other streams (Grzenda & Brehmer 1960, Kobayasi 1961, Flemer 1970).

The number of algal cells does not provide an unconditional measure of algal biomass. In samples in which cell size varies widely, cell number alone would only yield a rather arbitrary measure of algal biomass. However, the range of the cell size in the present material is small, and it therefore seems justifiable to use cell number as an approximate index of the actual biomass.

The amount of FPOM in relation to chlorophyll a concentrations displays several characteristics in the river Rickleån ecosystem. There is a time lag of 2-2.5 months from the spring flood with a FPOM peak to the

chlorophyll peak in July. During this period two different processes are working simultaneously: The FPOM concentration is decreasing step-wise, while the algal biomass increases successively. In the autumn, on the other hand, storms and floods raise the FPOM level, while algal biomass is successively levelling off.

It may be assumed that diatoms contain approximately 2 % of their dry weight as chlorophyll a (Berrie 1972, Marker 1976). If the chlorophyll values are transformed to biomass it is possible to compare the drifting algal material with the total FPOM concentrations. Hence, the biomass is expressed as a percentage of the total. During 1974-76 this percentage fluctuates from 1 to 17. It is also possible to structure the data by distinguishing different periods or seasons:

(1)	13-17 %	found at maximum algal biomass in July with FPOM values around 1 or slightly above
(2)	5-8 %	found at a) low or moderate values for both of the parameters b) temporary FPOM peaks summertime
(3)	1-2 %	found at high floods with high FPOM peaks

Thus, only during very short periods will living, algal biomass exceed 10 % on a weight basis of the total FPOM drift. At other times of the year it constitutes a minor share, with a modal value within the range 5-8 %.

In the literature, maximum values of 45 % (of the total seston) and 60 % (of the organic fraction) have been reported from the Thames (Berrie 1972).

6 BOTTOM FAUNA

6.1 Introduction

Since running waters include a gradient of sites from almost standing waters to very fast-running waters they are extremely variable biotopes. In one and the same water system the composition and the quantity of the bottom fauna mainly depends on temperature (incl altitude and season), water velocity, vegetation and bed topography (incl the substrate). In the Rickleån 7 habitats are recognized (tab 3), each of which has a more or less specific bottom fauna.

At an early stage I decided that the investigation should be limited to the bottom fauna of the main channel of the rapids. This delimitation was motivated by several factors: Firstly, I assumed that a high productivity occurred in the rapids, and especially the channel zones; secondly, this habitat is one of the dominating ones in the river, and, thirdly, little information was available about the "stone fauna" in the Rickleån. However, in 1974 I became interested in questions concerning the seston load. By then I had found that a large part of the benthic animals in the rapids were filter-feeders, and that there appeared to be a possibility of establishing a correlation between the benthic community and the seston load.

In the Rickleån earlier investigations of the bottom fauna have been made by Södergren (1969, 1973, 1974, 1976), Olsson (1970), Göthberg (1973, pers. comm.), and Karlström (1976 a). These investigations have dealt with drift phenomena, fauna elements of the *Fontinalis* community, life-cycle studies, and flight activity of Trichoptera imagines along the river.

6.2 Study areas

The bottom fauna was collected from two rapids in the Rickleån. At Storlångforsen the samples were taken approximately 15 m downstream of a road bridge (fig 27). Boulders

on the NE side of the river provided "stepping stones" to the channel zone of the rapids. During the winter these boulders were covered with a level surface of ice, which greatly facilitated the sampling procedure. The channel zone was always free of ice.

Samples were also collected from the upper rapids of Isakfäbodaforsen (fig 28, site A). Here the river bends and stone walls were erected in the 30's to enable floating of timber. The sampling site was situated just outside the stone wall on the inner bend (site A).

6.3 Method

Introduction

In general, sampling of bottom fauna in stony streams is a difficult task. A large number of different samplers have been proposed (Macan 1958, Edmondson & Winberg 1971), but none has gained universal acceptance, due to the variability of the stream substrates. Certainly, in stony streams the most convenient method is to take up stones individually (Schräder 1932) while holding a hand-net beneath the stone. However, this method is not without constraints.

When stones are sampled individually losses of different fauna components, e.g. net-spinning Trichoptera, are inevitable. In fact, the contact surface of two stones seems to be an important site for conglomerations of nets, pupae etc, and naturally these structures are effectively destroyed and lost when only one of the stones is removed.

From a practical point of view, the individual stone sampling method is done preferably in shallow water and under ice-free conditions. Such conditions are rarely met in a large river in northern Sweden, such as the Rickleån.

Sampling of individual stones will provide us with an approximate picture of the "stone fauna" but in the Rickleån, with its multi-layered bottoms in the rapids (fig 26), assemblages of plant material can be seen frequently

between and under the stones, especially in the spring and in the autumn. Furthermore, a multitude of transitions of the "stone fauna" community and the *Fontinalis* community can be found in the rapids. This implies that a "true stone fauna" in the Rickleån to some extent may be regarded as an artificial benthic community. The aspect of separating a "true stone fauna" is given a low priority in the present investigation.

To meet the constraints of the stone sampling method and also to enable comparisons between several streams by using a standard method, a number of colonization devices have been proposed. These devices are based on the concept that the organisms will colonize a long-term, exposed substrate. The running water as an ecosystem has a strong potential for colonization of denuded areas or exposed substrates (Müller 1953, Waters 1964), which certainly favours the use of colonization devices. However, it seems that this approach of using a colonization device for sampling the bottom fauna was first used in connection with lake studies (Moon 1935). In running waters the method has been employed by several workers (Wene & Wickliff 1940, Hester & Dendy 1962, Henson 1965, Mason et al. 1967, 1973, Anderson & Mason 1968, Bull 1968, Ulfstrand 1968, Hilsenhoff 1969, Dickson et al. 1971, Ulfstrand et al. 1974). A tray, a basket or a cage containing stones or artificial substrates is usually placed directly on the bottom, but the container may also be allowed to hang freely in the water attached to a buoy (Mason et al. 1967, 1973, Roux et al. 1976). Today, the colonization method seems to have its most extensive application in biological monitoring and recipient control programmes (Scott 1958, Mason et al. 1973, Arthus & Horning 1969, Dickson et al. 1971).

Sampling device

In the Rickleån a wire basket with 14 cm high sides was filled with 12-18 stones of approximately fist-size, or a little larger (fig 29). The stones were taken from the river bed and were brushed free of visible invertebrates. 3-5 coloniza-

tion baskets were exposed from 30 days to 5 weeks as a rule; in the winter the exposure time was sometimes 2 months. The projected surface of each stone was measured, i.e. maximum length by maximum width, and the sum of all projected stone surfaces in a basket made up one sample unit, usually 15-18 dm^2. To enable comparisons the abundance and the biomass are expressed per m^2.

The baskets are lifted, with two special handles, out of the water. During this procedure a loss of organisms takes place, which was estimated tentatively by holding a construction of nets with a mesh size of 250 µm below and downstream of the baskets (fig 30). The net-catch, which represent the loss, is expressed as the percentage of the recorded number of individuals or biomass of the basket sample. The evaluation of the method, including a discussion of its constraints, is given in section 6.4.

It was assumed that submersed stones differ strongly from dry, never submersed stones in specific surface characteristics as state of chemical weathering and development of the organic layer. Results from a pilot study in 1973 supported this assumption. Therefore, only stones from the river were used in the colonization baskets.

Material

Colonization baskets were exposed and sampled at Storlångforsen and at Isakfäbodaforsen from July 1973 to October 1975 (sampling at Storlångforsen ended in May 1975). The total material includes 82 sample units from 20 occasions at Storlångforsen and 55 sample units from 13 occasions at Isakfäbodaforsen.

This chapter discusses only a part of the total material, i.e. the development of the bottom fauna at Storlångforsen is followed during 1973 and 1974. A comparison of the two sampling stations is made, but only concerning material collected during the summer-autumn in 1974. The remaining material will be dealt with in other publications.

Sample treatment

After exposure the baskets were taken up and placed in wide plastic jars. Each stone was carefully brushed with a paint-brush in order to remove all animals. Usually, plant material had fastened to the sides of the baskets and between the stones within the baskets. The plant material on the sides was discarded, while the material within the basket was regarded as a part of the sample.

All material was preserved in formalin, approximately 4%, in the field, or within 3 hours. During the summer all samples were preserved in the field. Later, after sorting, the animals were preserved in a solution of formalin and ethanol (3 parts of 4% formalin, and 7 parts of 70% ethanol).

All individuals were sorted out and counted, except for Simuliidae and Chironomidae. The abundance of these two groups was estimated by subsampling (Södergren 1974). However, some of the samples - all those from 1973 and those from 1974 with relatively few individuals - were not subsampled. In these samples from 1973 no attempt was made to sort out all small chironomids (<1.5 mm of length) and simuliids (<2.0 mm) but, on the other hand, all were counted and biomass corrections were made, and thus are included in the abundance and biomass data given below.

The organisms were weighed on an analytical balance to 0.1 mg, after having been dried on blotting-paper until no fluid could be seen on the body surfaces.

Nomenclature

The systematic nomenclature follows Limnofauna Europaea (Illies 1978), with the exception of the Trichoptera. Regarding this order the check-list by Svensson & Tjeder (1975) is followed.

6.4 Results and discussion

Constraints of the method

The total loss of animals from the baskets, in terms of number of individuals or biomass, is very small, as indicated by a compilation of net-catches (tabs 28 and 29). Mean total losses are 3-4% and the maximum loss is 8%. On the other hand some species seem to be lost to a great extent. Within the Ephemerida species, excluding *Heptagenia dalecarlica*, the net-catches make up 30-40% as a mean, and >100% as extreme values. Also some plecopteran species, e.g. *Isoperla grammatica* and *Amphinemura borealis*, are lost to a substantial degree. Apparently, these groups are very mobile, while more sessile groups, such as filtering Trichoptera and Diptera are only lost to a small extent. Since the sessile, filtering species, and some other species (e.g. *H. dalecarlia* with flattened body, *Rhyacophila nubila* with abdominal hooks) strongly dominate the species composition of the stone fauna, the total loss of individuals is small.

The baskets were exposed to swift, running waters, 1-1.5 m s^{-1}, and sometimes in rather deep water, 1-1.2 m. Under such conditions an evaluation by aid of nets is bound to underestimate the losses of animals at sampling. Although the loss percentage was relatively low in this study I am not convinced that the net-catches fully reflect the actual loss and thus the data on abundance and biomass should be regarded as rather conservative, i.e. minimum values.

An alternative arrangement is to keep a folded net under the basket during the exposure time, and, at the moment of sampling, unfold it and cover the whole basket. This procedure was rejected for two reasons. Firstly, the net under the basket acts as a trap for FPOM, and the net itself is a colonization surface. This has been demonstrated by Winterbourn (in press) who found large quantities of organisms in exposed bags, regardless of whether they were empty or filled with leaves. Dudley Williams & Hynes (1974) also emphasize the role of the nets as detritus-traps. Secondly, it is a very inconvenient method in a larger stream, as the Rickleån.

The assessment of abundance and biomass for production studies in running waters is faced with great problems. It has been conclusively demonstrated that the extension of the bottom fauna is considerable in depth (see the review of Dudley Williams & Hynes 1974). One of the mechanisms for this is the migration of the benthic organisms, which means that the method of sampling individual stones will yield only a portion of the total benthic fauna. The colonization baskets with two layers of stones probably compensate somewhat for this underestimate, but on the other hand the colonization method faces other problems.

The number of individuals and the amount of biomass varied considerably between the sample units. This is illustrated by the data from one sampling occasion in July, 1974 at Isakfäbodaforsen (tab 30). One implication of the large variation is that the mean abundance or biomass of the population cannot be estimated by any satisfactory level of precision. An increased number of sampling units, or the development of a stratified sampling programme, would probably reduce the variation but to a considerably higher time-cost; an objective that would have been difficult to realize within the frame of the present investigation. Furthermore, changing water levels may lead to a rather extensive programme for stratified sampling.

As a consequence, the data on abundance and biomass in this study are not regarded strictly as quantitative, but merely semi-quantitative i.e. the estimates are conservative, minimum values of the true population abundance and biomass.

Qualitative composition

All species and higher taxonomic entities found in the channel zone, by means of the colonization baskets, have been compiled (tab 31). A tentative comparison of the species composition and the abundance of the channel zone with those of other habitats has been included in the table. It should be noted that the very extensive list of

Trichoptera is based mainly on determination of imagines by Anders Göthberg, Rickleå field station. We do not know whether all species are true inhabitants of the Rickleån; they might just as well have dispersed from other bodies of water. From the basket samples a few single Trichoptera larvae of the eruciform type have not been determined.

There are some notable differences between the fauna of the channel zone and that of other habitat. Representatives of Oligochaeta and *Asellus aquaticus* are sparsely found in the basket samples, while they are very abundant in the sediment of the slow-flowing parts of the Rickleån. This also applies to *Ephemera vulgata*, although the species can be found abundantly in sandy parts of the rapids, e.g. the lower part of Isakfäbodaforsen.

In general, representatives of Plecoptera are more abundant in the rapids compared to other major habitats (tab 3); however, the colonization baskets fail to include the whole *Fontinalis*-community where a large number of Plecoptera also can be found. This applies also to some Coleoptera species, e.g. *Elmis aena, Limnius volckmari, Oulimnius tuberculatus*.

The trophic category of filter-feeders is very characteristic for the stony substrates of the channel zone, e.g. the trichopterans *Hydropsyche instabilis, H. nevae, H. pellucidula, Cheumatopsyche lepida, Arctopsyche ladogensis,* and the whole family of Simuliidae.

The trichopteran *Brachycentrus subnubilus* was very seldom found in the colonization baskets, although it has been reported to be very abundant in the channel zone just below the outlet of Lake Bygdeträsket.

Biomass

The seasonal development of biomass of the bottom fauna has been compiled for Storlångforsen (fig 31). Based on this material an annual cycle of the bottom fauna may be distinguished, covering roughly three periods: (1) Winter, low biomass, (2) spring-early summer, peak values, and (3) summer-autumn, moderate biomasses, fluctuating more or less around a steady level.

Since the biomass values given here only represent the bottom fauna of the upper part of the bottom, the estimated level of the absolute biomass should be regarded as tentative. For instance, the formation of anchor ice may release a vertical migration of the bottom fauna down in the bed, and consequently, the colonization baskets will catch only a smaller portion of the previous population inhabiting the exposed stones. The phenomenon of vertical migration in connection with anchor ice has been reported for salmonid fishes, especially in connection with electro-fishing (Östen Karlström, pers. comm.).

The trophic category of filter-feeders strongly dominates the bottom fauna community of the channel zone (tab 32). During the late winter and early spring the biomass level is successively built up. In the beginning of July the filter-feeders make up 86% of the total community on a biomass basis. After that the proportion of filter-feeders to the total community decreases. During the winter 1973/74 the total biomass level as well as the percentage of the filter-feeders is low. This may be due to migration since ice conditions are severe during this season.

It should be noted that the stated proportion of the filter-feeders may be a little bit too high. One of the constraints of the sampling method is that some groups are lost more easily than others. Generally the filter-feeders are more sessile, and therefore they may be somewhat over-represented in the samples.

Systematically the filter-feeders belong to mainly two groups, net-spinning Trichoptera and Simuliidae. Since they are rather sessile they are likely to be involved in a spatial competition with each other. However, in the Rickleån the mass development of the two groups occur at different seasons. Simuliidae reaches its biomass maximum in early June, and constitutes 78% as a mean of the total sample, while the net-spinning trichopterans culminate in late September. This time-niche differentiation favours a high and steady level of biomass of the community.

Comparison between two localities

The biomass data of two localities in the Rickleån have been compiled from July to September 1974 (tabs 33-35). Sampling in one of the rapids was always followed the next day by sampling in the other rapids.

There is a general accordance in fauna composition of the two rapids; the same groups dominate and the community structure appears to be the same. However, both qualitative and quantitative differences exist between the rapids. Since the method is only semi-quantitative, small, but actual differences are not possible to analyse in this context.

The species *Eomystra intermedia* and *Ancylus fluviatilis* were never found in Storlångforsen, indicating different distributional patterns compared to the other components of the stone fauna community. This was first noticed by Södergren et al. (1976).

Another gastropod, *Lymnaea peregra* is found in higher amounts in the lower rapids.

On all three sampling occasions *Heptagenia dalecarlica* reached higher biomass levels in Isakfäbodaforsen.

The main difference between the two localities is the stronger development of the filter-feeding component in Storlångforsen. This is very apparent for Simuliidae, *Hydropsyche instabilis*, *H. nevae*, but not for *Arctopsyche ladogensis*, which dominates in the lower rapids.

Not surprisingly, the biomass of *Rhyacophila nubila* was found to be largest at Storlångforsen. *R. nubila* is a predator, and although it may be rather opportunistic - as most predators are - the main food item in the Rickleån is Simuliidae.

What are the environmental conditions that favour the strong development of the filter-feeders in Storlångforsen? The

two localities differ somewhat in water velocity and substrate. Due to aggregation of large boulders, forming stepping stones out into the river (see p 49), the sampling site at Storlångforsen is located far out in the channel zone. At Isakfäbodaforsen, on the other hand, the water velocity is somewhat lower and the boulders are rather smaller than at the sampling site in Storlångforsen. Other factors, such as the distribution patterns of the *Fontinalis* mosses within the rapids may also be involved in this question. A more definite statement about the causal relationship of the community structure of the bottom fauna will have to be based on specially designed field experiments.

To conclude this section, the comparison between the two localities revealed some consistent patterns which were apparent on all three sampling occasions. Moreover the consistency demonstrates the reliability of the colonization basket method, within the constraints discussed.

7 SUMMARY

1. The aim of this study is to give a description of a forest river in Northern Sweden, the Rickleån, and its responses to drainage basin processes. Within the general objective for the study, particular interest is focused on the sources, transport, and turnover of detrital matter.

2. The Rickleån drainage basin has a total area of 1673 km^2, stretching 110 km in a NW to SE direction. The basin includes both the coast and a part of the taiga belt of northern Sweden.

3. The river's discharge regime is bimodal, with the maximum peak in the spring, sometimes 160-180 $m^3\ s^{-1}$.

4. The river course alters between rapids and slowly flowing sections. Water mosses are abundant in the rapids. A further subdivision of habitats in relation to water velocity, substrate and vegetation has been elaborated (tab 3).

5. The river water can be characterized as humic and slightly acid; pH around 6. Conductivity is around 3.5 mS m^{-1}. Considering the major constituents, the Rickleån is a calcium sulphate water.

6. Considering the minor constituents, the concentration of NO_2+NO_3 ranged from 14 to 160 µg N l^{-1}. Phosphate concentration, referring to the fraction reactive to molybdate, ranged from 1.6 to 10 µg P l^{-1}. No depletion of NO_2+NO_3 or PO_4 seemed to take place during the years of investigation.

7. The autumn leaf-fall into the river was estimated by means of leaf-traps. Data from different types of bank vegetation ranged from 7 to 42 g d.w. m^{-2} or from 273 to 1048 g d.w. m^{-1} shoreline.

8. From the leaf-fall data and comparison with litterature data it is concluded that the impact of riparian vegetation on the river's metabolism is relatively small.

9. The transport and composition of LPOM was measured by means of collection-bags. The relative transport during 3 months in connection with the ice-break constituted nearly 72 % of the total transport. The composition revealed a distinct seasonal pattern, and as a whole water mosses and small fragments (mostly mosses) were dominating. From the data it is concluded that the water mosses constitute the base substrate for the detrital processes in the river.

10. The fragmentation and decomposition rate of *Populus tremula*, a common riparian tree along the Rickleån, was measured during the autumn by the weight loss of leaf-packs. Depending on several factors such as the initial amount, condition, water temperature etc the loss rate ranged, after 1-2 months, from 0.45 to 1.02 per cent day^{-1}.

11. The amount of organic material coating the stones in the river was estimated by brushing the stones. In relation to the projected surface of the stones the confidence limits ($p<0.05$) of the mean (35) was 30-40 mg ash-free d.w. dm^{-2}.

12. Different factors that govern the development of the organic layer are discussed and listed in a scheme (tab 16).

13. The organic layer of small stones and pieces of plastic film, previously exposed in the river, was examined by scanning microscopy. It revealed very complex, multistoreyed stryctures. The presence of a large number of Fungi and Actinomycetes suggests that these play a relatively active role in detrital turn-over compared to the bacteria.

14. Community respiration of the organic layer of the stones was measured in closed chambers with circulating water. It ranged from 0.17 to 1.15 g $O_2 \cdot m^{-2}\ d^{-1}$ in the interval 11-20°C.

15. A compilation of all available data on community respiration from the Rickleån, which includes three levels ofbenthic substrates, showed a range from <1.1 to 5.5 g $O_2\ m^{-2}\ d^{-1}$.

16. The amount of DOM was determined by dichromate oxidation and ranged from 15 to 110 mg O_2 l^{-1}. The seasonal variation was smaller than the diurnal one. No obvious seasonal pattern was discernable.

17. The ratio of DOM to FPOM showed a modal value in the range of 17 to 25. The extreme range was 7 to 39.

18. The major portion of the DOM originated from humic compounds. Therefore it is concluded that the measured amount of DOM is mostly refractory, and that its impact in promoting heterotrophic growth is small.

19. The concentration of FPOM showed a distinct seasonal pattern with an extreme range from 0.2 to 5.7 mg l^{-1}. The modal value was around 1 mg l^{-1}.

20. The concentration of FPOM can be reasonably predicted by the discharge, although exact statements of short-term peaks require an intense effort.

21. FPOM with a diameter of approximately <25 µm strongly dominated the composition of the seston. Frequently this fraction made up 85-94 % on a weight basis.

22. Chlorophyll a concentration varied from 0.2 to 3.5 mg m^{-3}, with lowest values during December-April. Peak values were found roughly during the first part of July.

23. Chlorophyll a was concluded to be an acceptable estimator of algal cell number and biomass. It was calculated that algal biomass constituted a minor share of the total FPOM drift; the modal value was 5-8 % of the total.

24. The bottom fauna of the rapids was studied by means of colonization baskets filled with stones from the river and exposed one month.

25. The possibilities and constraints of the colonization method are extensively discussed (part 6.4). The conclusion is drawn that the method should be regarded as semi-quantitative as to the abundance and biomass.

26. The trophic category of filter-feeders was very characteristic for the stony substrate of the channel zone,e.g.

the trichopterans *Hydropsyche instabilis, H. nevae, H. pellucidula, Cheumatopsyche lepida, Arctopsyche ladogensis*, and the whole family of Simuliidae. As a maximum the filter-feeders constituted 86 % of the total community on a biomass basis.

27. Generally the biomass of the bottom fauna fluctuated around or a bit below 10 g w.w. m^{-2}. Lowest biomass records (1.5 - 3.6 g m^{-2}) were found in mid and late winter. The maximum values were found in early June, as the spring flood was beginning to decline, and ranged from 37 to 135 g m^{-2} (67 g m^{-2} as a mean for this period).

8 ACKNOWLEDGEMENTS

I would like to thank all friends and colleagues at the Rickleå field station and at the Department of Ecological Zoology, University of Umeå, for practical help, advice, and criticism; I am particularly grateful to Sten Backlund, Anders Göthberg, Torbjörn Johnsson, Robert Petersen, and Sam Södergren.

I am also grateful to Professor Arne Lindroth who made this work possible by inviting me to Umeå in 1972.

Most of the field work and the daily routine work would have been considerably more difficult, and sometimes impossible without the assistance of our technician, Göte Andersson. My thanks are due both for assistance and friendship over the years.

Lab ass Arvid Sjöberg has always been interested in developing routines for physical-chemical water analysis. Without his interest and skilful work that part of the thesis would have been much smaller. I am glad to acknowledge his work in this respect.

The laborious, critical examination of the manuscript was made by Professor Birger Pejler, to whom I am most grateful. Professor Wilhelm Rodhe has also read the manuscript and gave valuable criticism, which I am pleased to acknowledge.

Financial support was given to the Rickleå Field Station by the Swedish Natural Science Research Council and by the foundation "Seth M. Kempes Minne", Örnsköldsvik.

Barbara Brammer and Nigel Rollison have kindly helped me with the English revision.

The drawings were made by Görel Marklund, Umeå and Björn Andersson, Uppsala.

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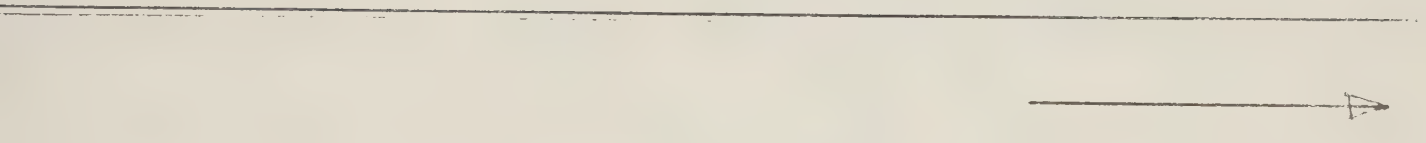
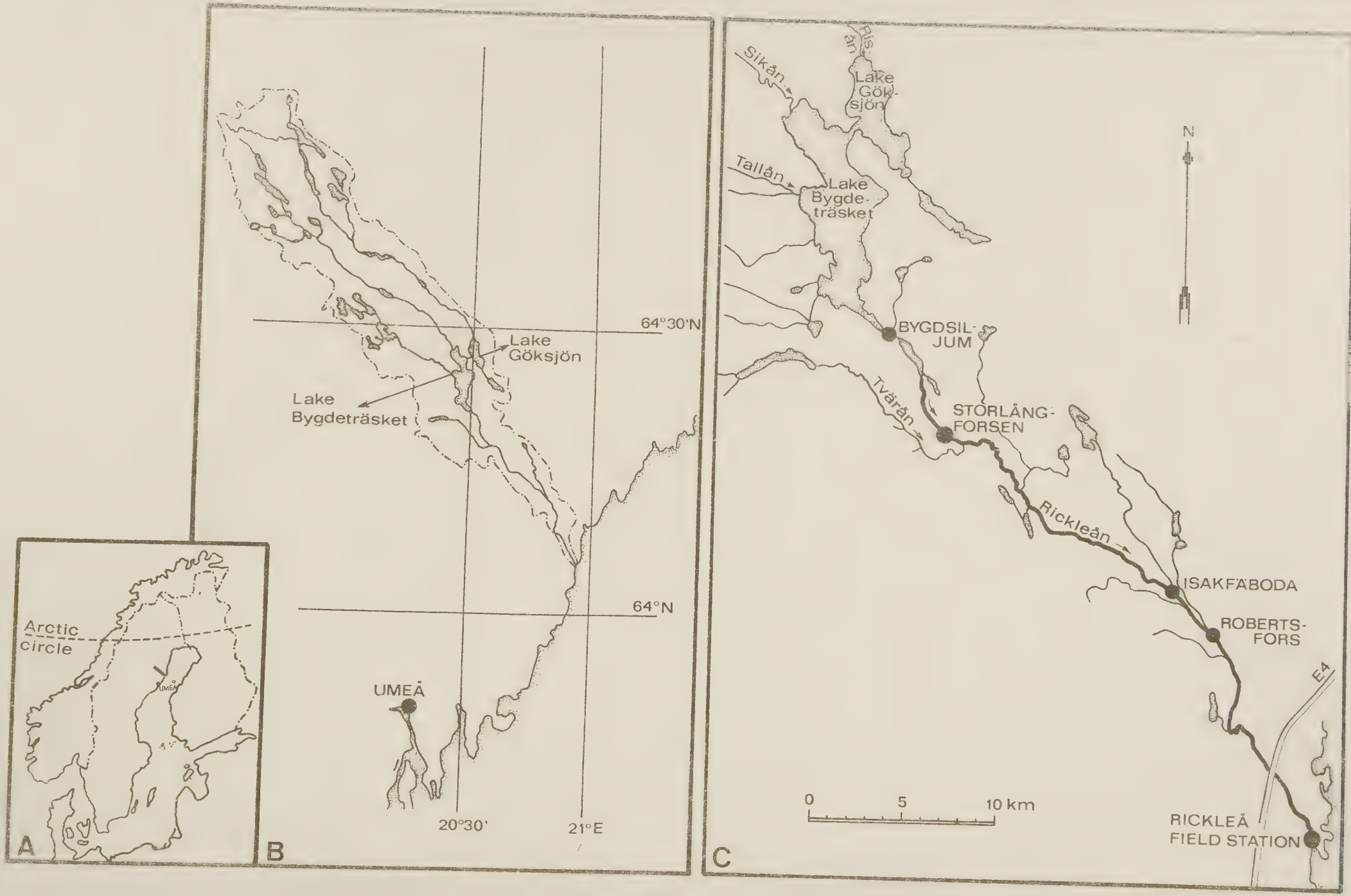


Fig 1. Rickleån River drainage basin. A-B, the position of the basin in Sweden. C, lower part of the drainage basin with the two small communities and the sampling stations marked.


A
Arctic circle
UMEÅ
B
64°30'N
64°N
Lake Göksjön
Lake Bygdeträsket
UMEÅ
20°30'
21°E
C
Risån
Sikån
Lake Gök-sjön
Tallån
Lake Bygde-träsket
N
BYGDSIL-JUM
Tvärån
STORLÅNG-FORSEN
Rickleån
ISAKFÄBODA
ROBERTS-FORS
E4
0
5
10 km
RICKLEÅ FIELD STATION

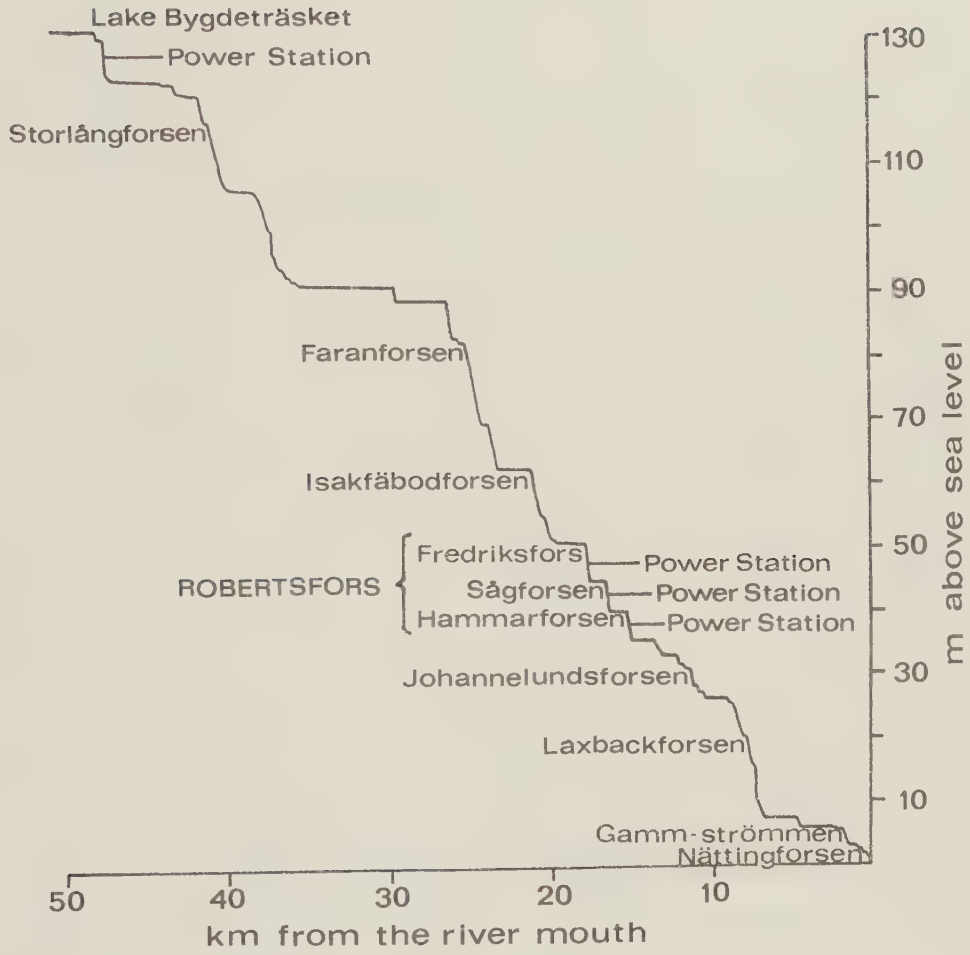


Fig 2. Slope curve for the Rickleån with sampling stations in the rapids marked.

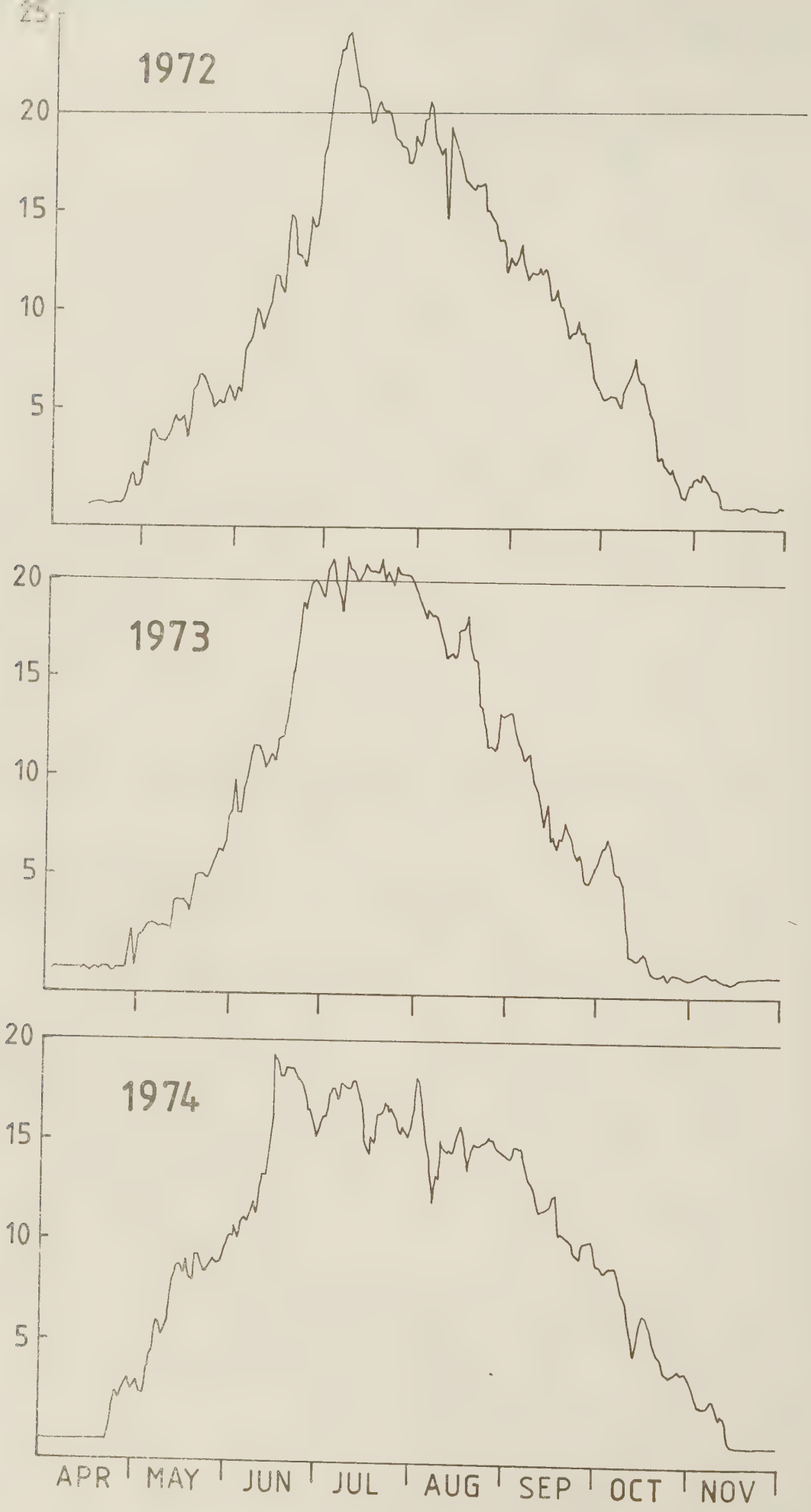


Fig 3. The mean weekly water temperature at the field station, the Pickhå, 1972-74

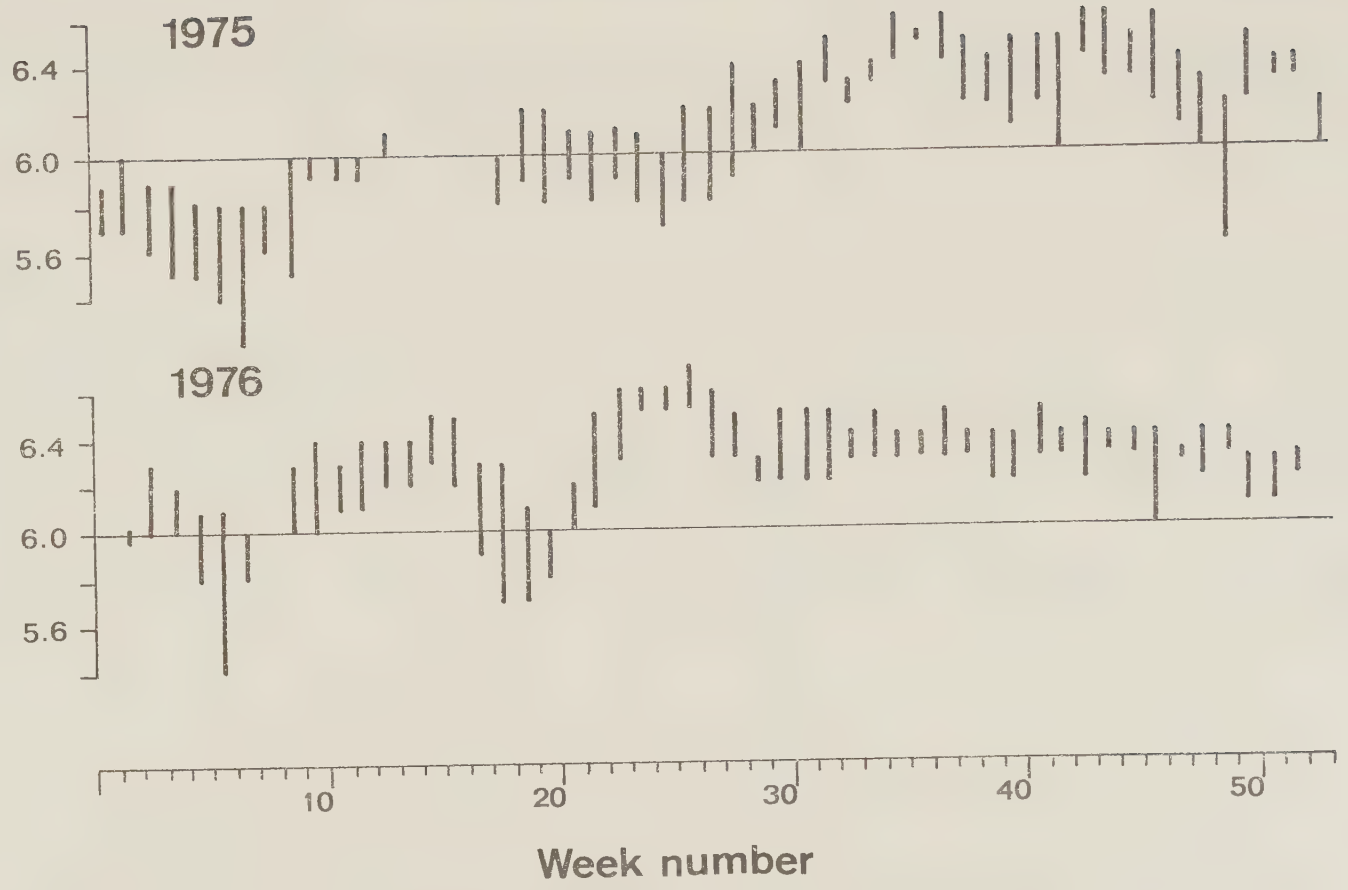


Fig 4. Weekly range of pH at the field station, the Rickleån 1975-76.

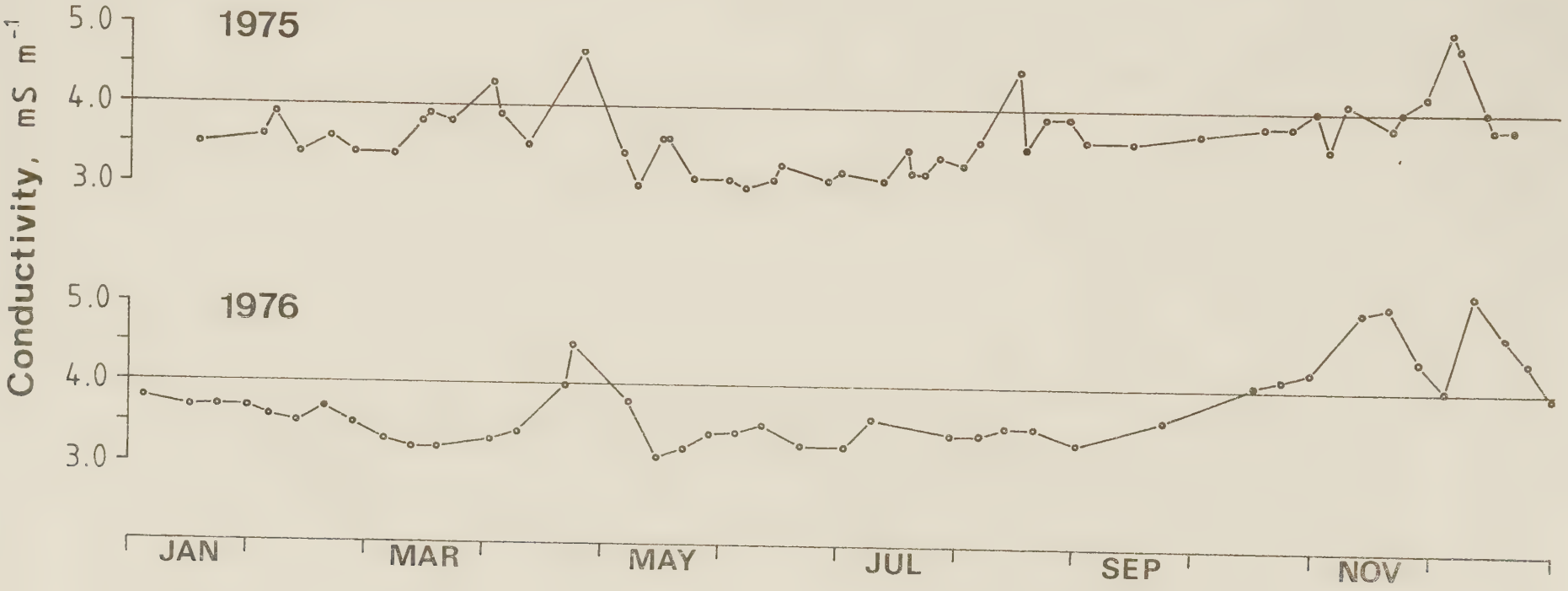


Fig 5. Weekly records of the conductivity, in mS m^{-1}, at the field station, the Rickleån, 1975-76.

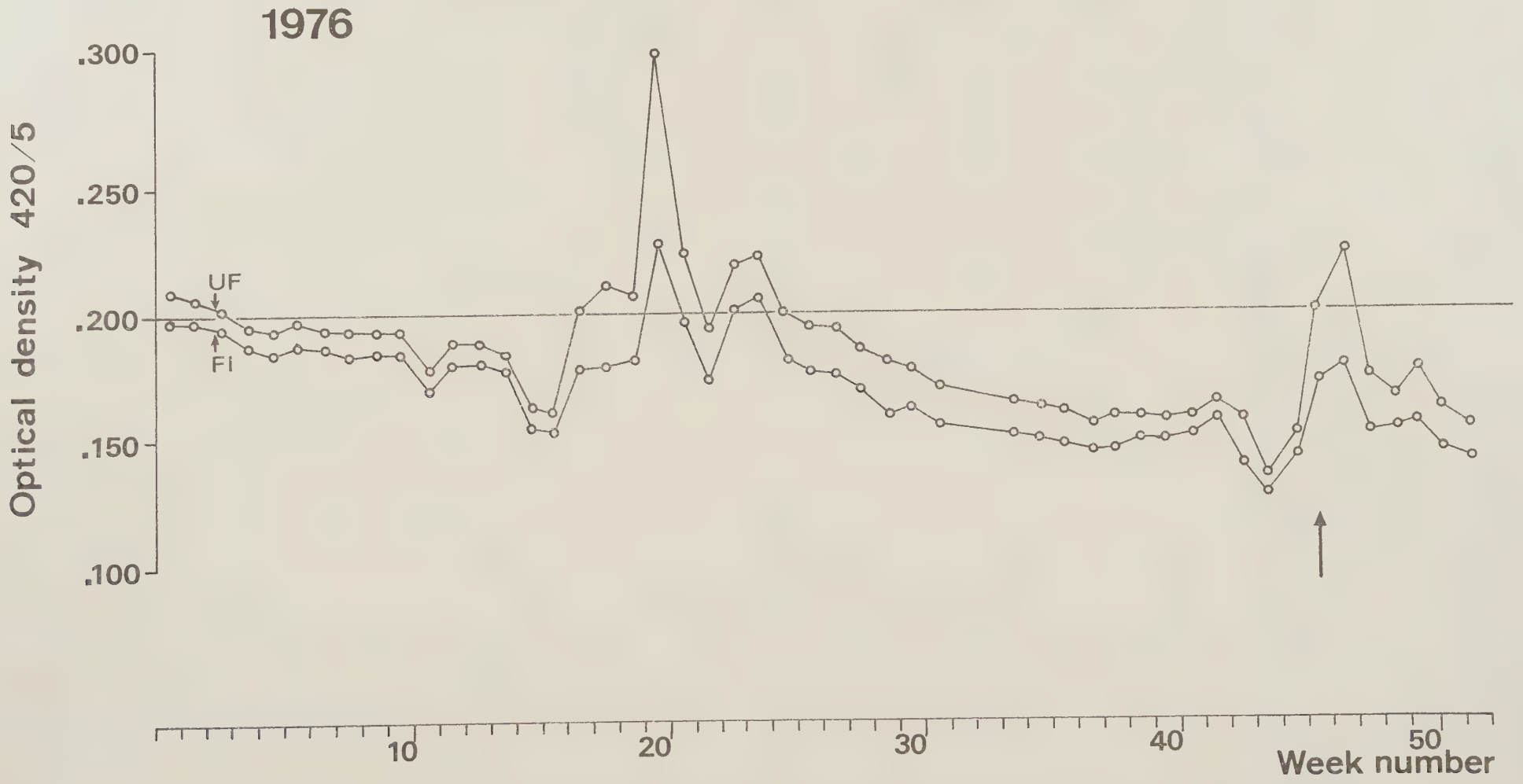


Fig 6. Weekly mean of the optical density (420/5) for unfiltrated (UF) and filtrated (FI) samples at the field station, the Rickleån, 1976.

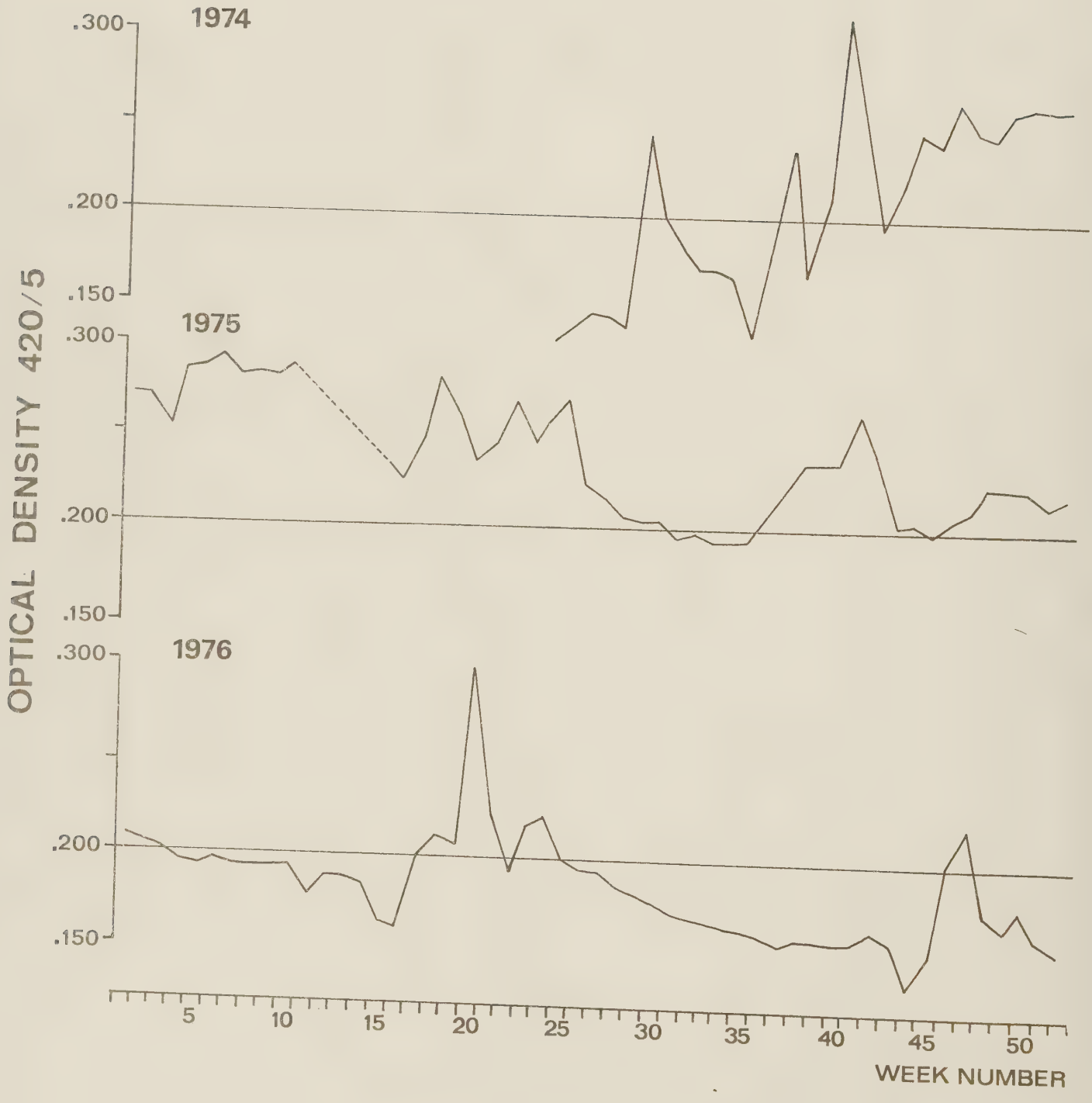


Fig 7. Weekly means of the optical density (420/5) for unfiltrated samples at the field station, the Rickleån 1974-76.

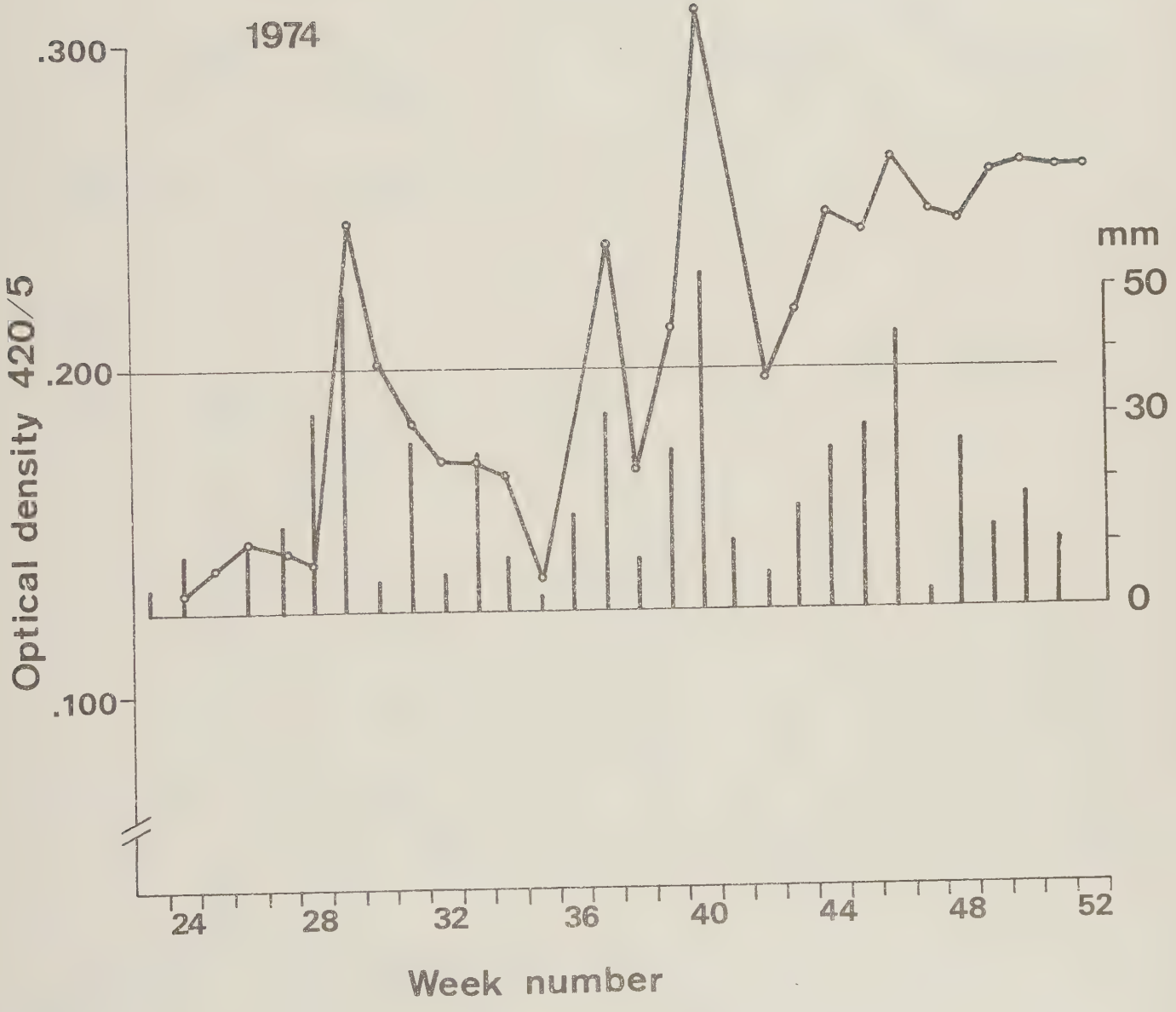


Fig 8. Weekly mean of the optical density (420/5; the curve) and weekly cumulative precipitation (mm; the bars) at the field station, the Rickleån, 1974.

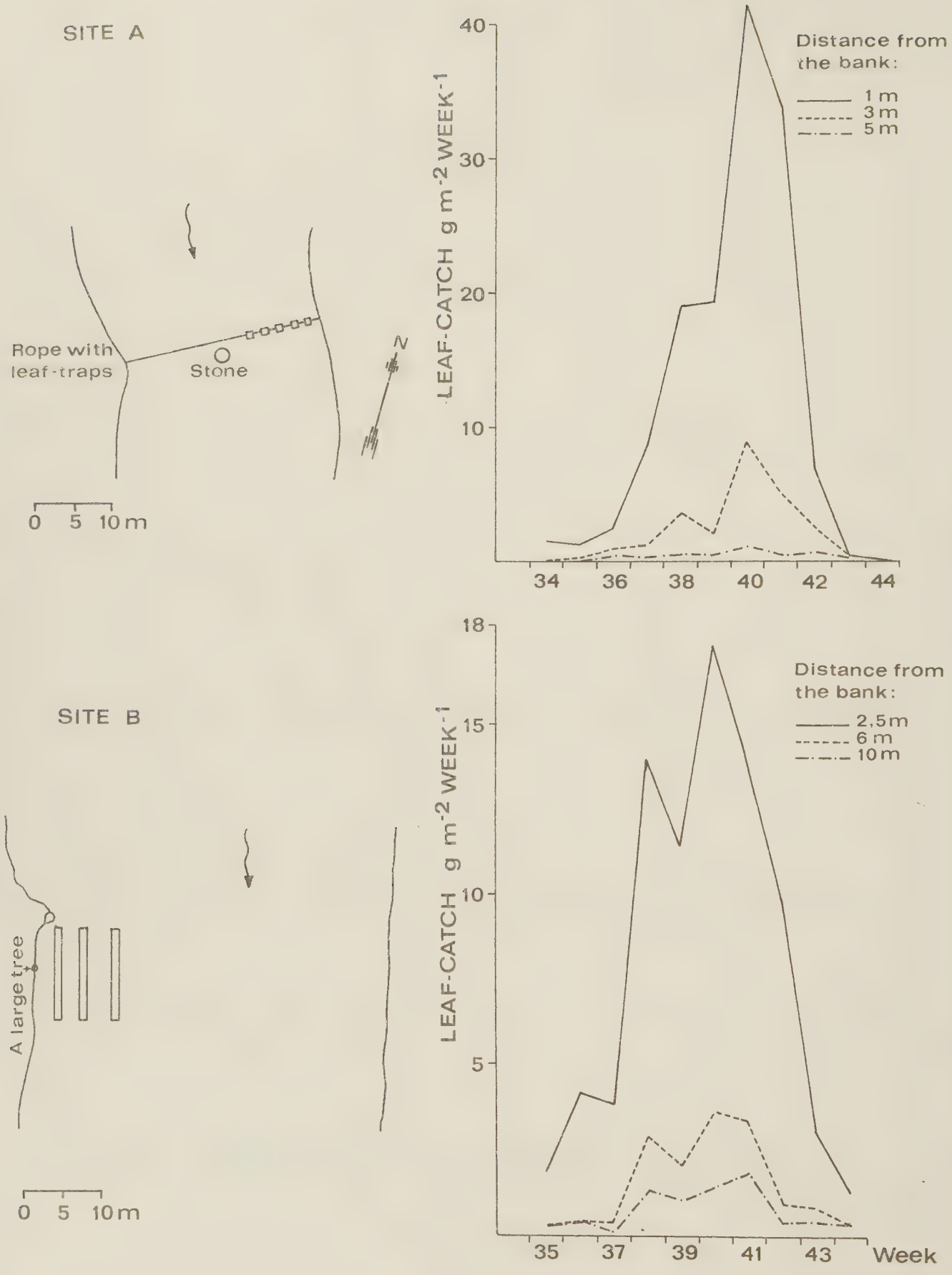


Fig 9. Weekly cumulative leaf-fall (g m^{-2} $week^{-1}$) at two sites (A, B) along the Rickleån, 1975.

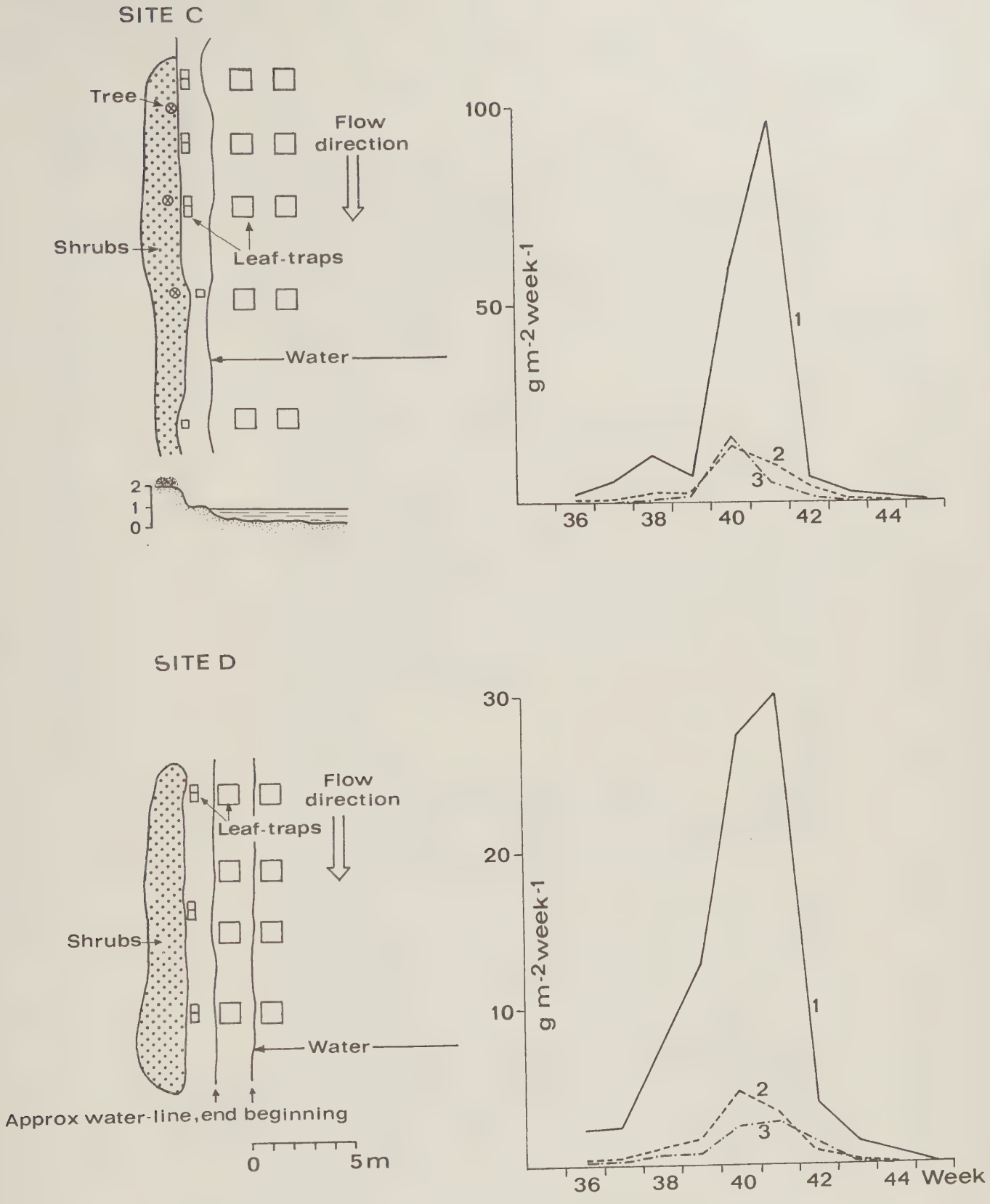


Fig 10. Weekly cumulative leaf-fall (g m^{-2} $week^{-1}$) at two sites (C, D) along the Rickleån, 1976.

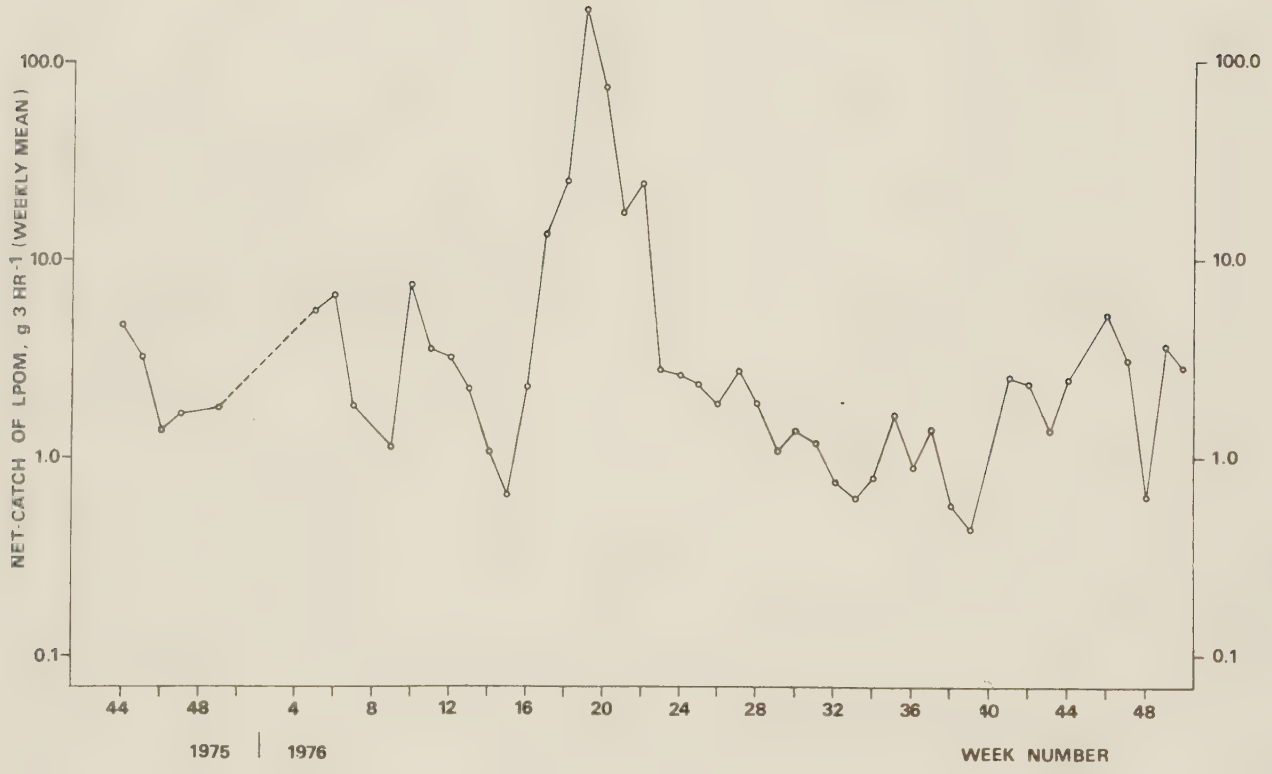


Fig 11. Weekly mean of the relative transport of large particulate organic materials at the field station, the Rickleån, 1975-76.

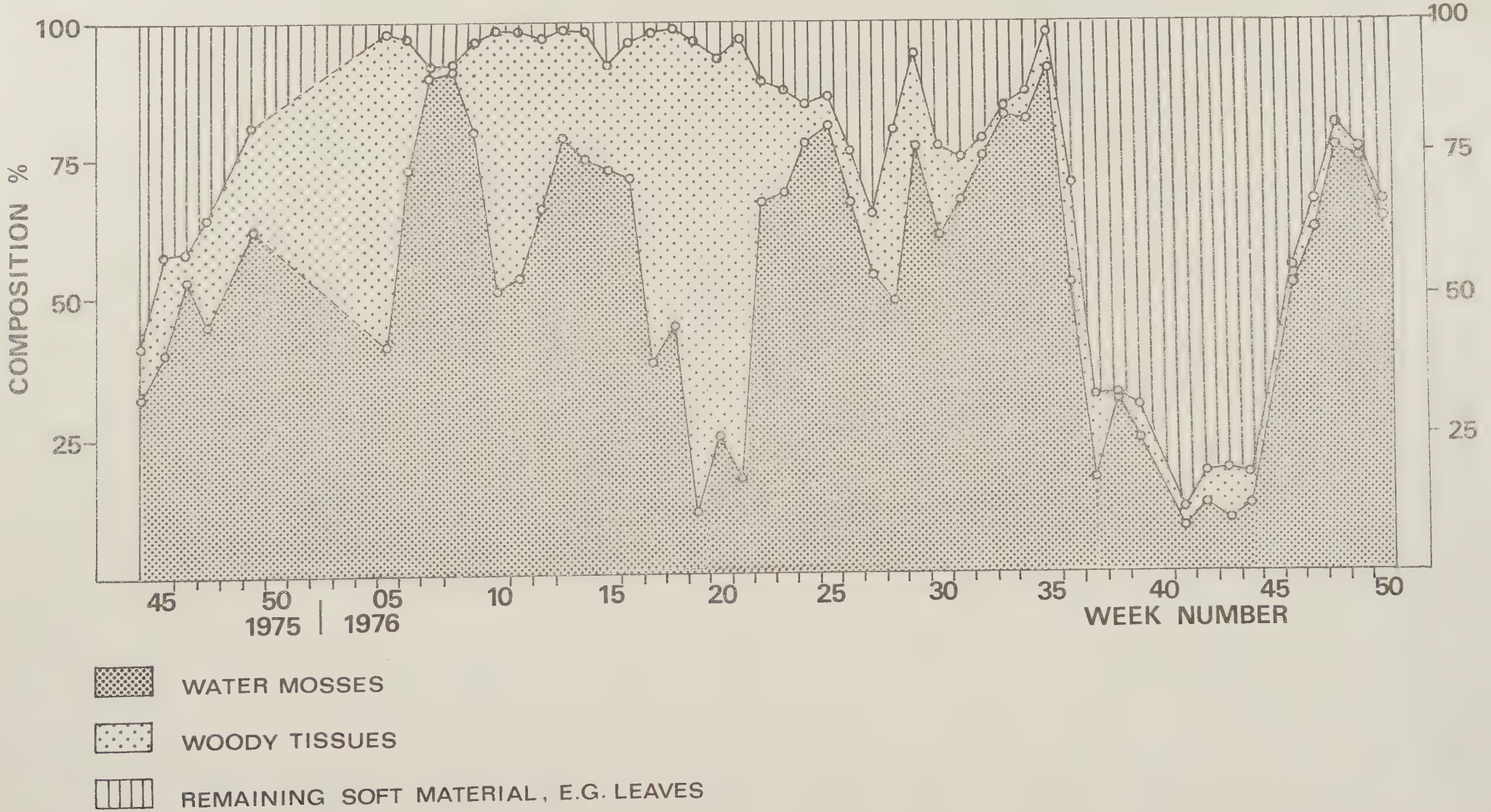


Fig 12. Weekly mean of daily composition (in %) of the transport at the field station, the Rickleån, 1975-76.

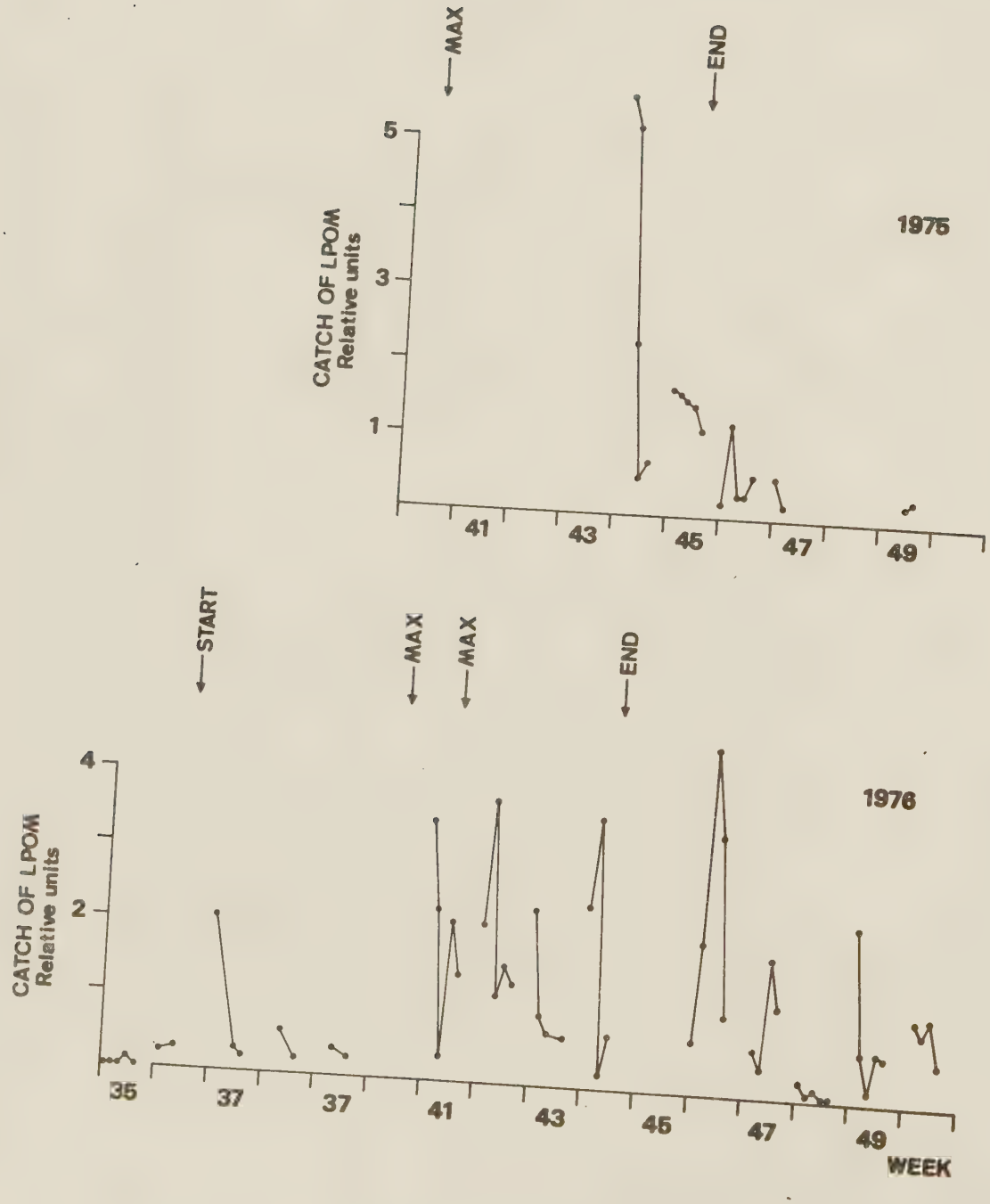


Fig 13. Leaf-fall (start, maximum, end) in relation to relative transport of leaves (daily net-catches, g 3 hrs^{-1}) at the field station, the Rickleån, 1975 and 1976.

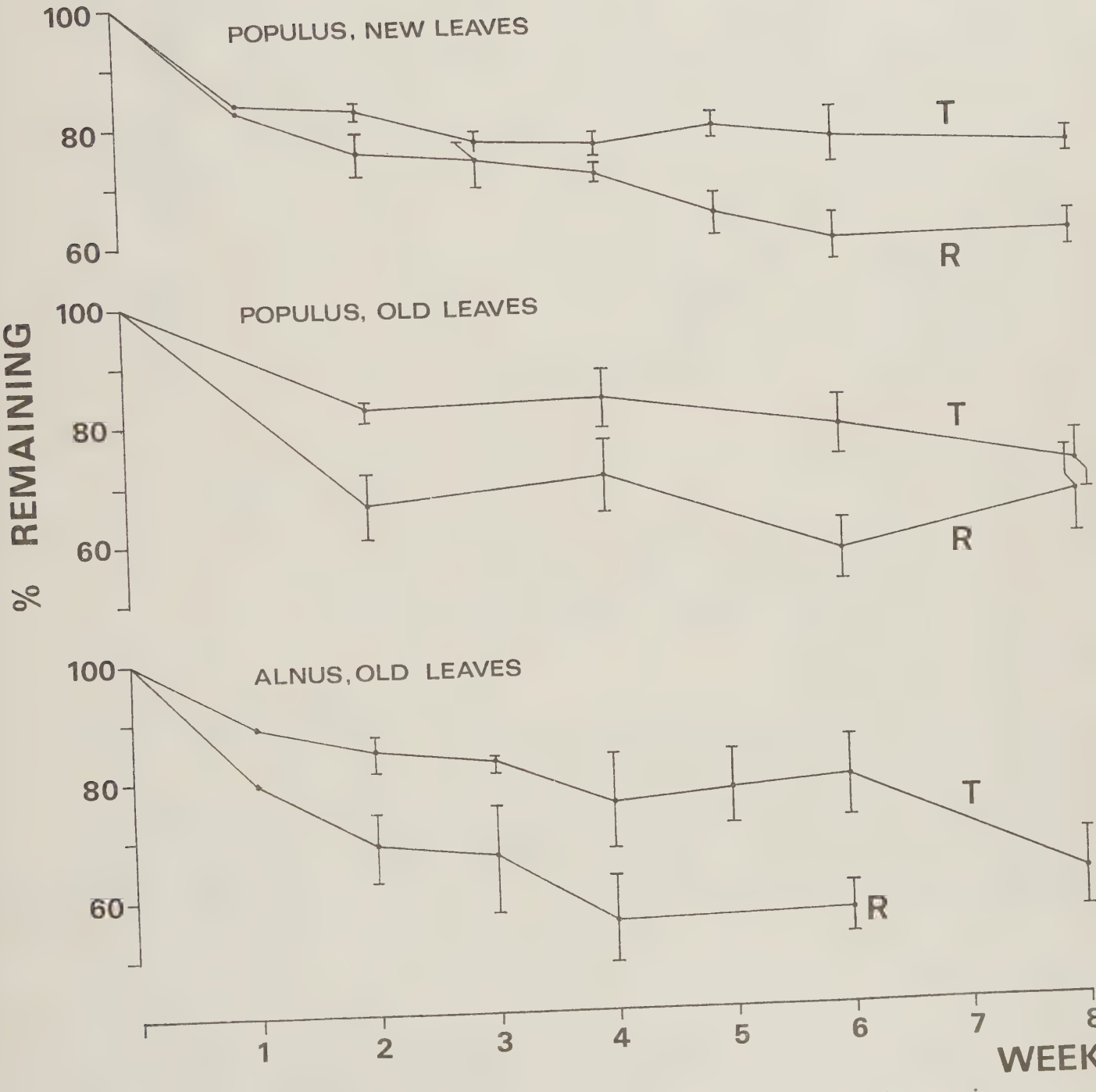


Fig 14. Weight loss of leaf-packs with different leaf species (see the text for explanation) exposed up to 8 weeks in a small tributary, the Tryssjöbäcken (T) and the Rickleån (R), 1974. Mean $\pm$ SD.

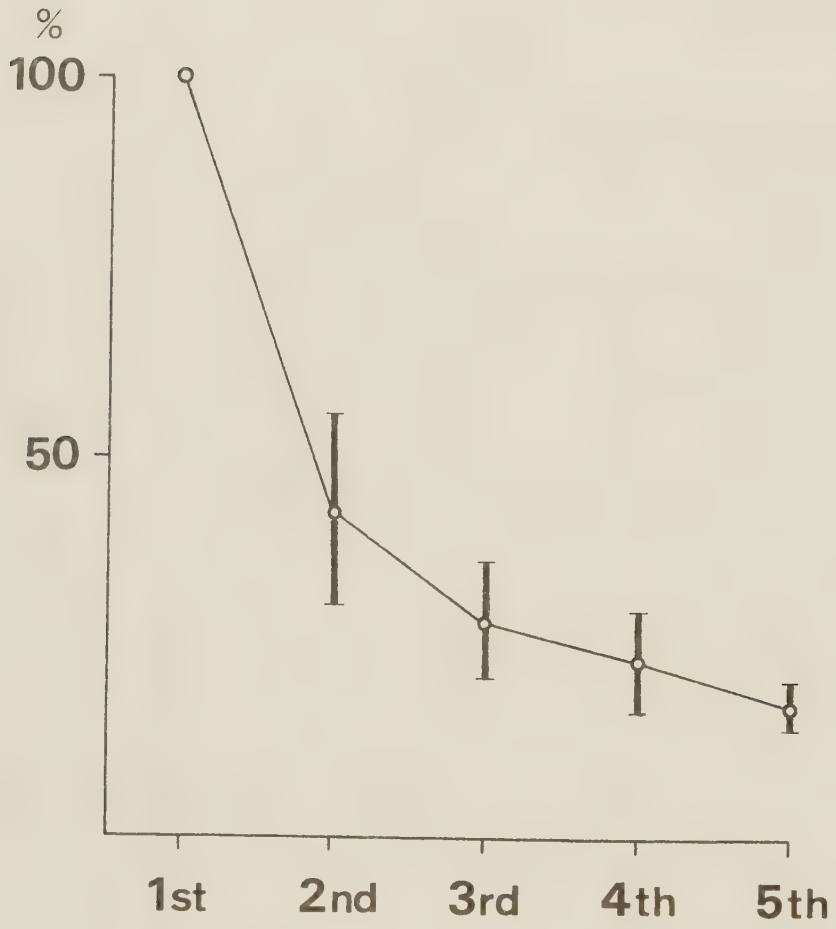


Fig 15. Numbers of wire-brushing needed to remove the organic layer of a stone from the Rickleån, 1975. Mean ± SD of 5 series.

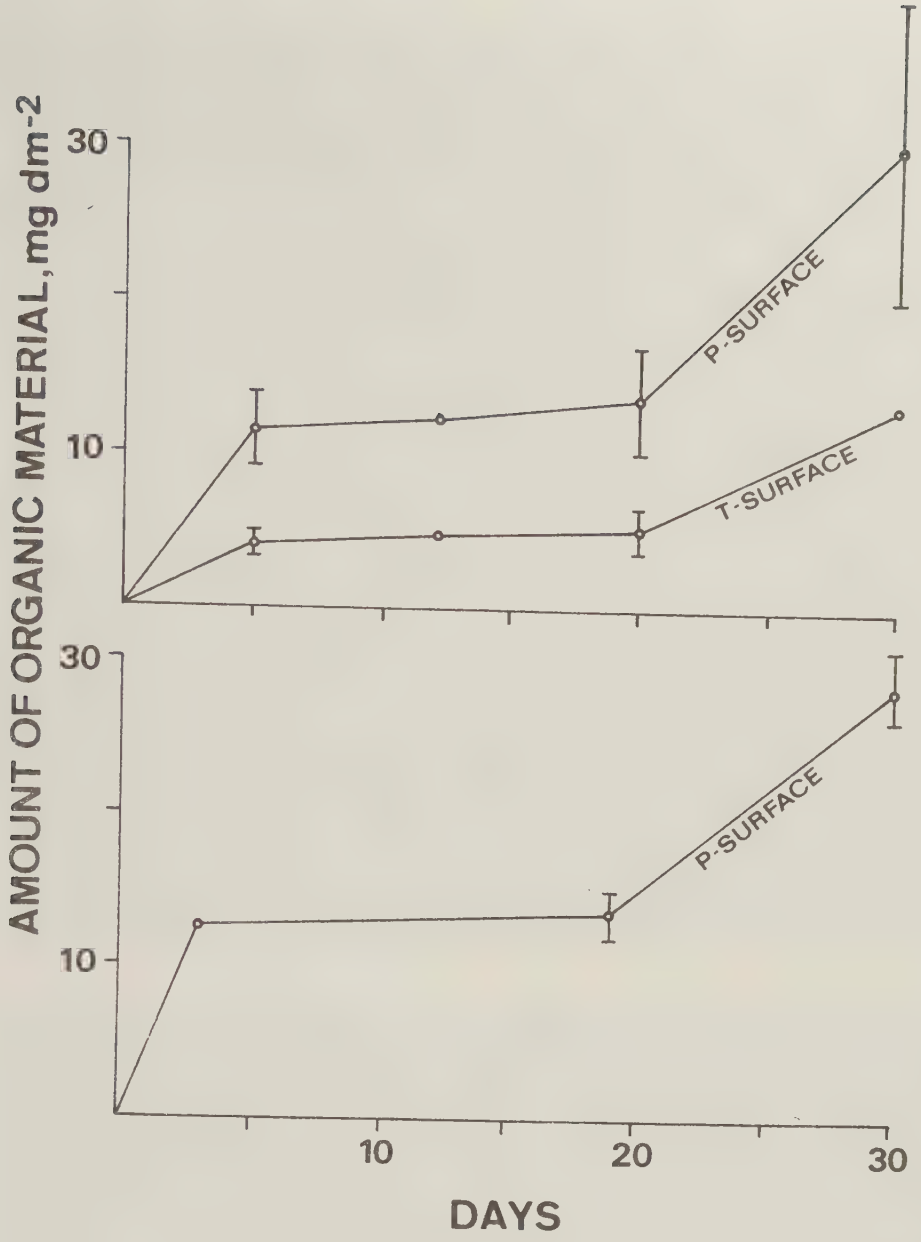
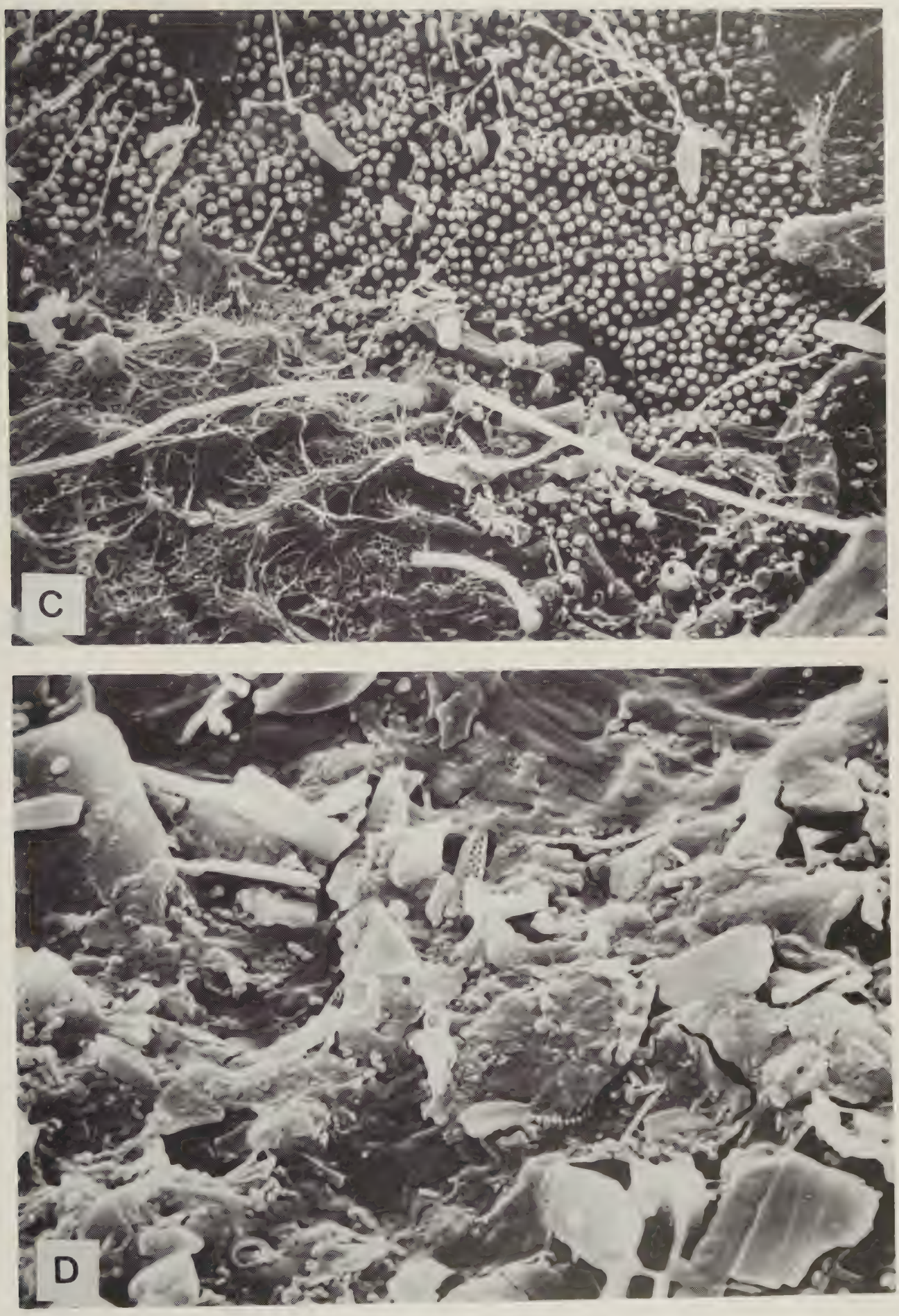


Fig 16. Colonization of organic material on brushed stones at two occasions in the Rickleån, 1975. Mean and range in mg. For explanation see the text.

Fig 17. SEM photographs of the organic layer of stones and artificial substrates from the Rickleån. A (120 x) and B (750 x); stones from the Isakfäboda rapids, October 25, 1976. C (1500 x); stones from the Isakfäboda rapids, September 26, 1976. D (7400 x); glass slides exposed 2.5 months during darkness, the Isakfäboda rapids, September 26, 1976.

A

B


C
D

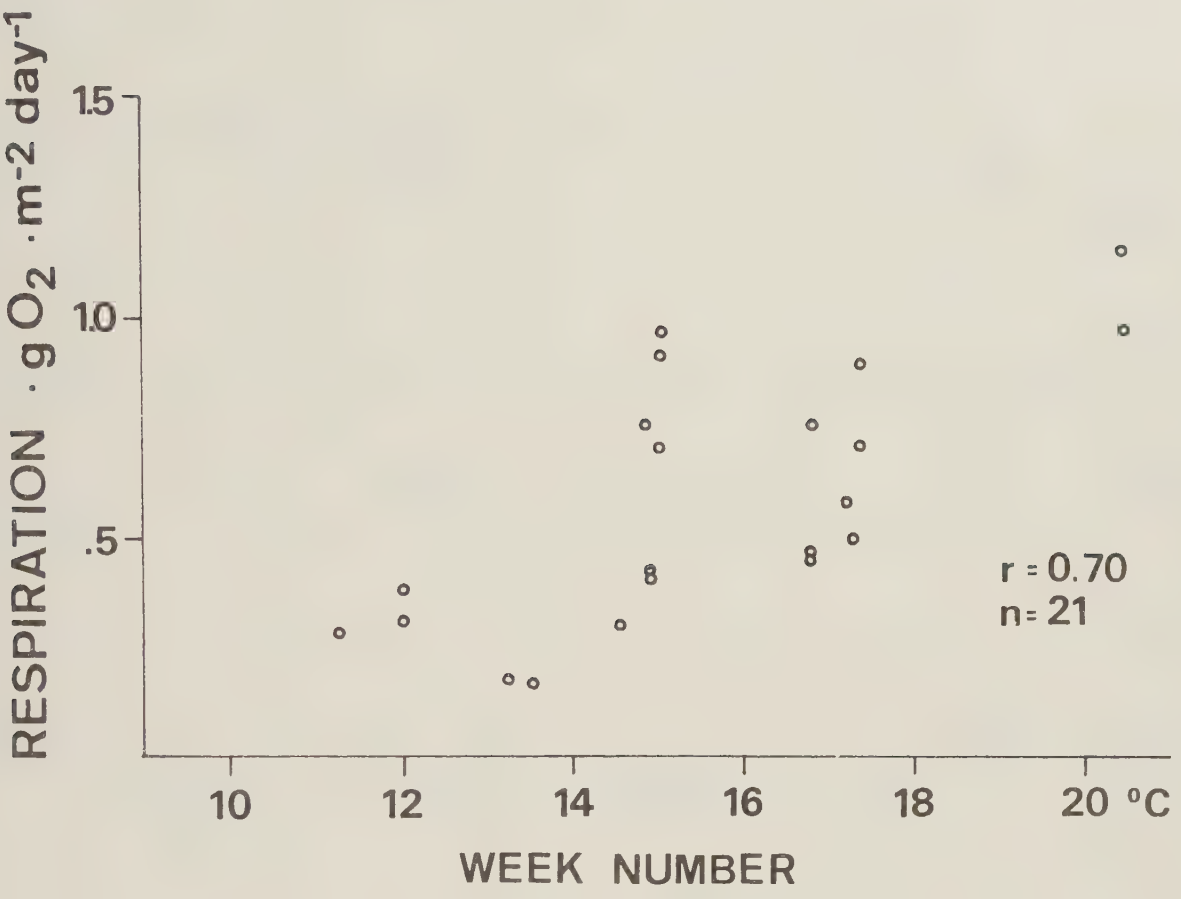


Fig 18. Respiration rate of the organic layer on stones from the Rickleån in relation to temperature during the investigation period in 1975.

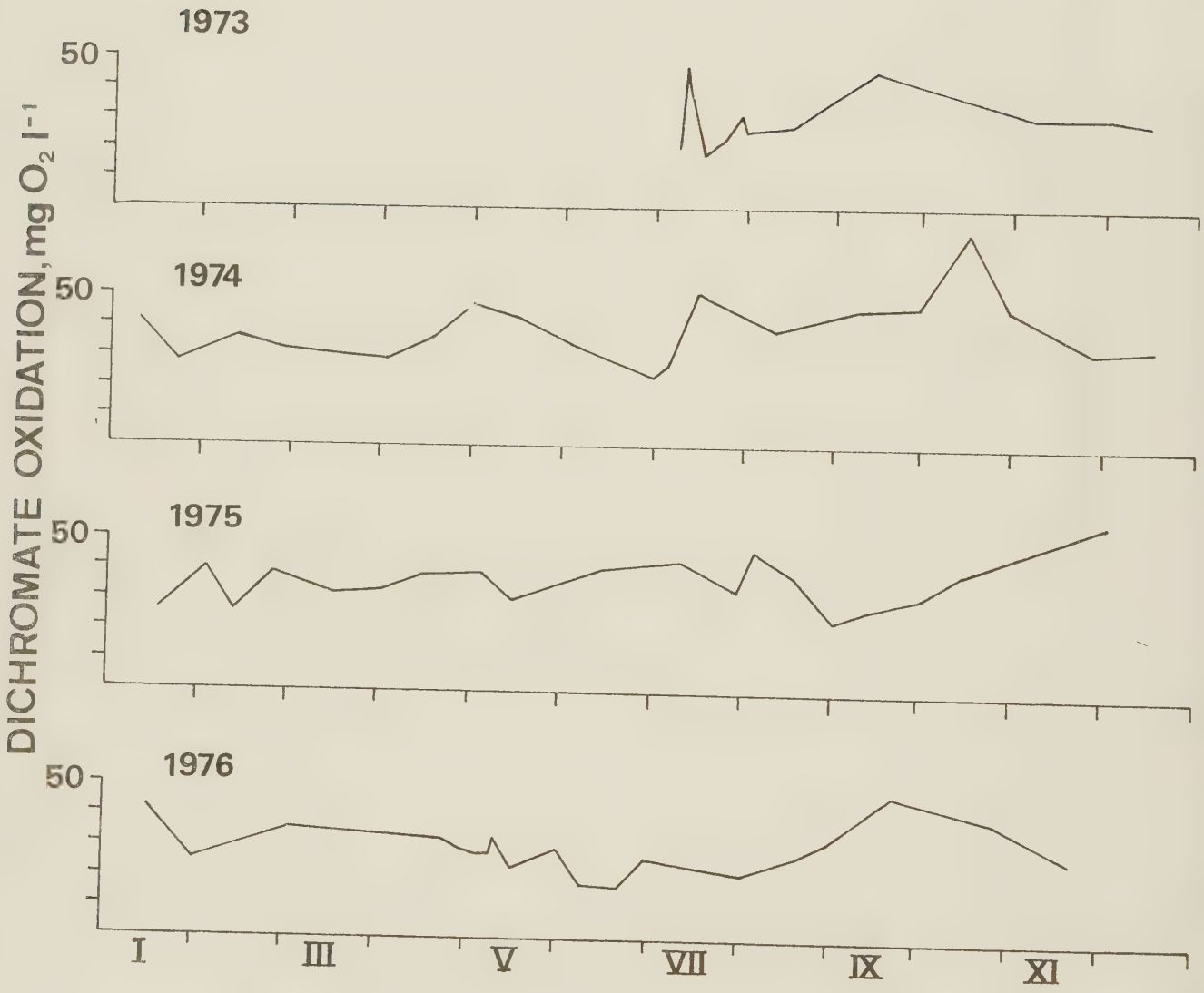
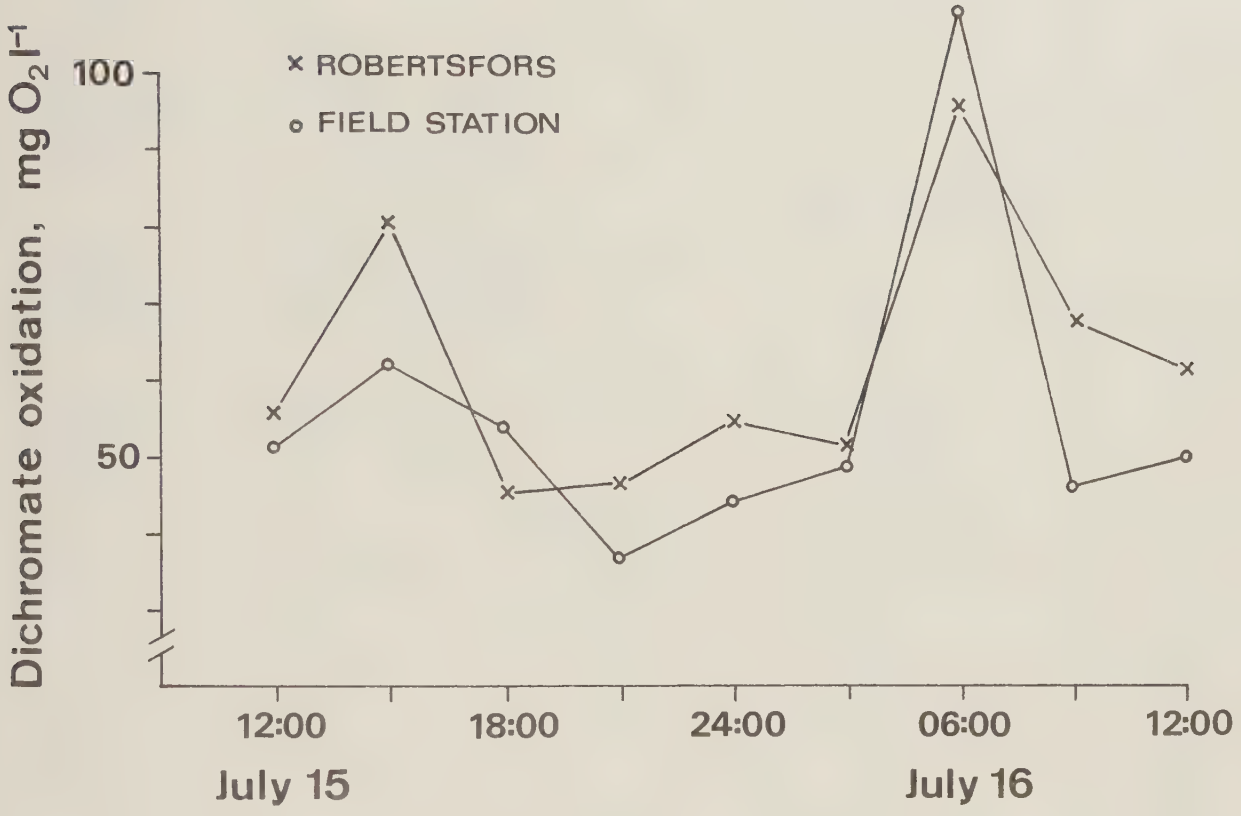


Fig 19. The concentration of dissolved organic matter (dichromate oxidation) at the field station, the Rickleån, 1973-76.



PRECIPITATION IN MM, JULY 13-16, 1974

Hour	13	14	15	16
7 a.m	-	-	12.5	0.7
1 p.m.	-	0	5.3	0
4 p.m.	0.1	-	1.4	0

Fig 20. Diel variation of dissolved organic matter at Robertsfors and the field station, the Rickleån, and precipitation at the field station.

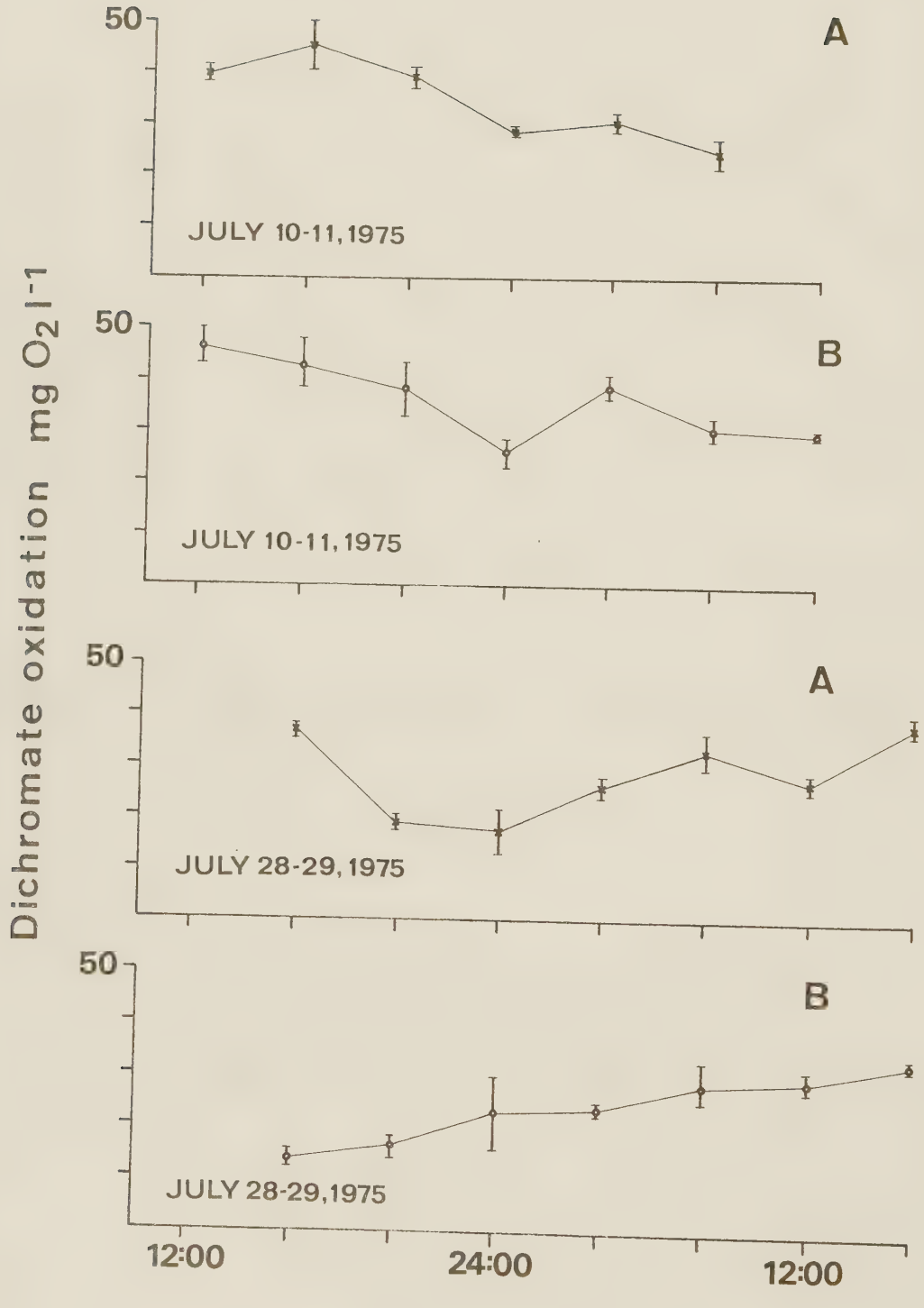


Fig 21. Diel variation of the concentration of dissolved organic materials during two 24 hours series at Robertsfors (A) and at the field station (B), the Rickleån, July 1975.

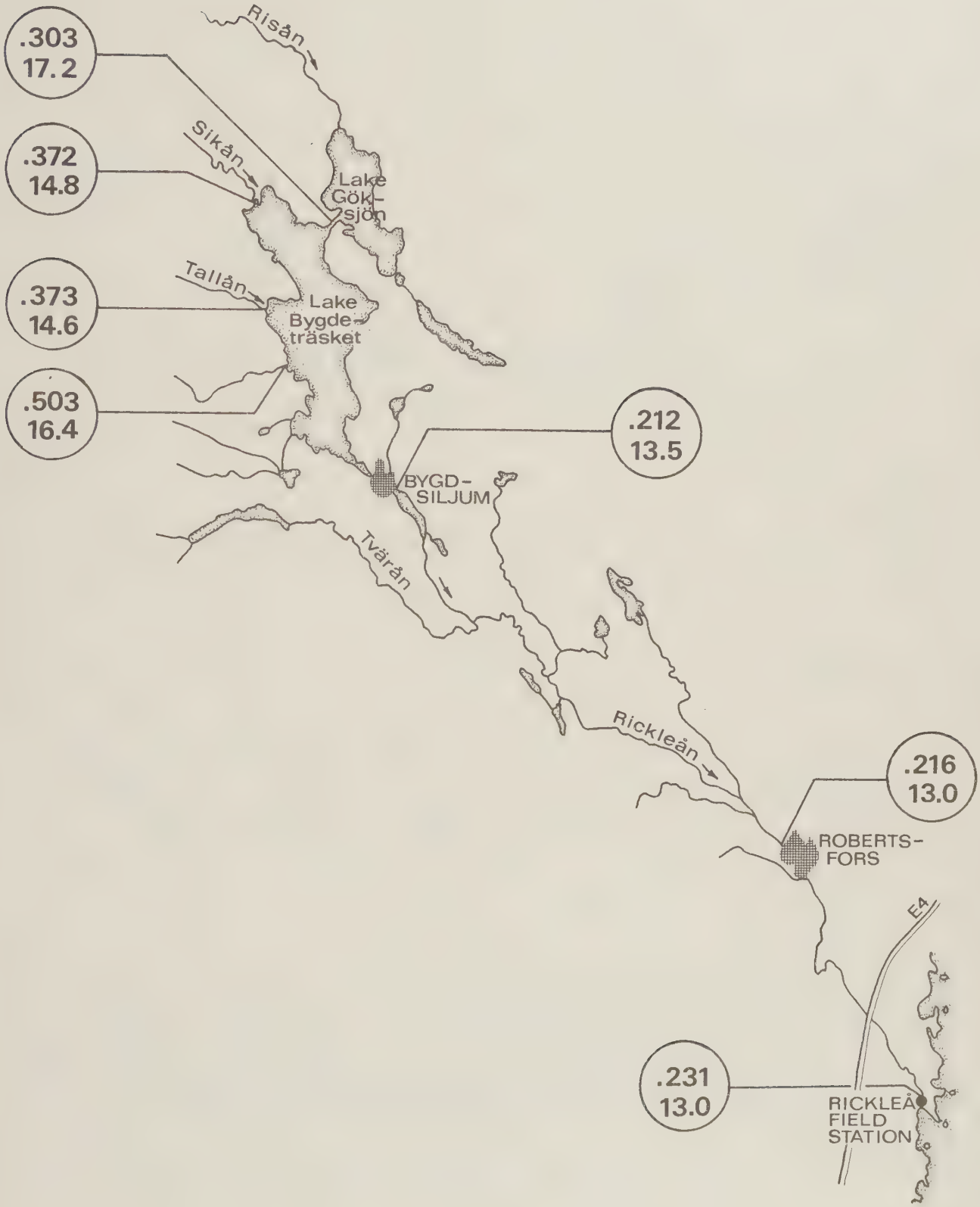


Fig 22. Optical density 420/5 (upper figure) and amount of humic compounds in mg l^{-1} (lower figure) at 7 stations in the lower part of the Rickleån drainage basin, December 5, 1974.

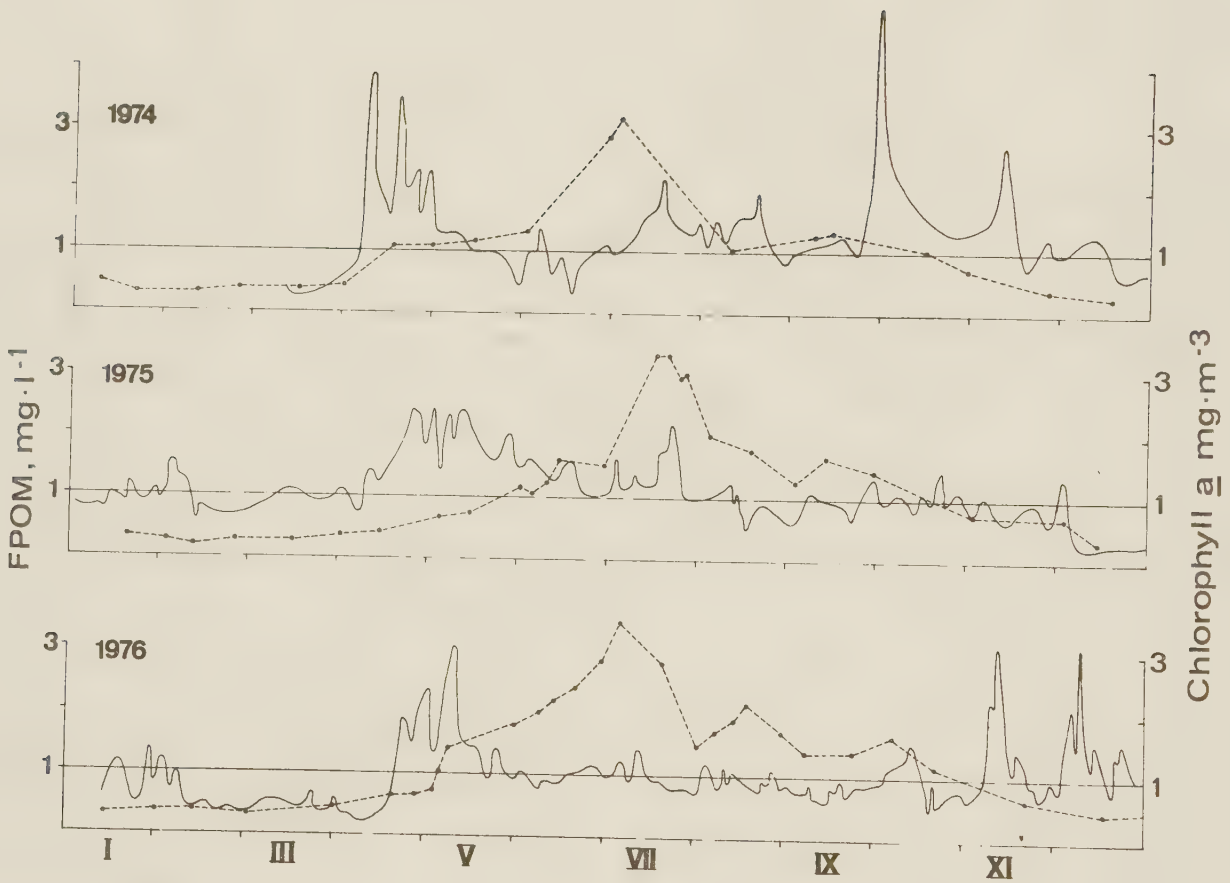


Fig 23. FPOM concentration in mg l^{-1} (the curve, and the scale to the left) and chlorophyll a concentration in mg m^{-3} (broken lines, and the scale to the right) in the Rickleån, 1974-76.

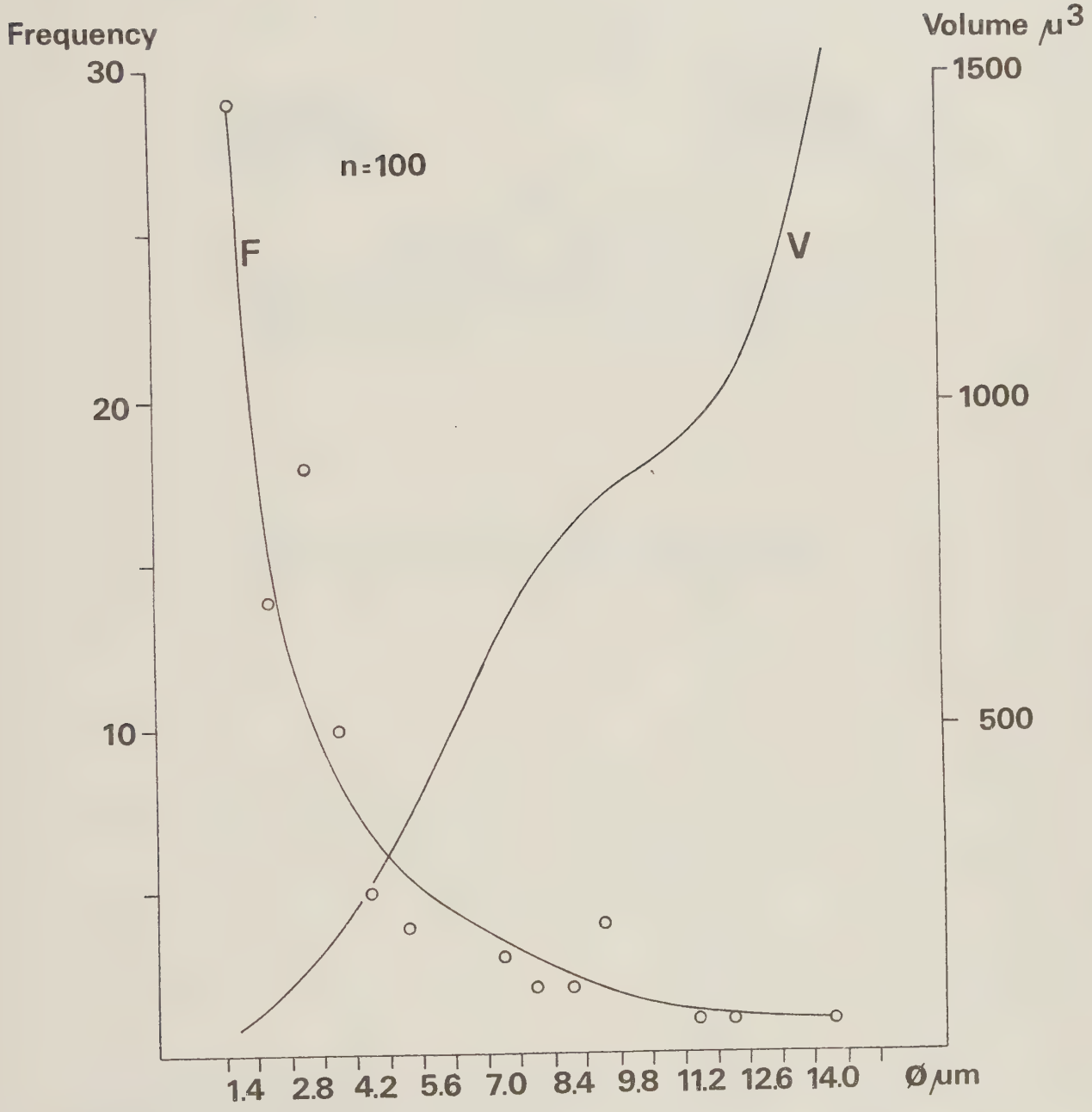


Fig 24. Particle size distribution of the seston at the field station, August 3, 1976. Counted frequency and calculated volumes.

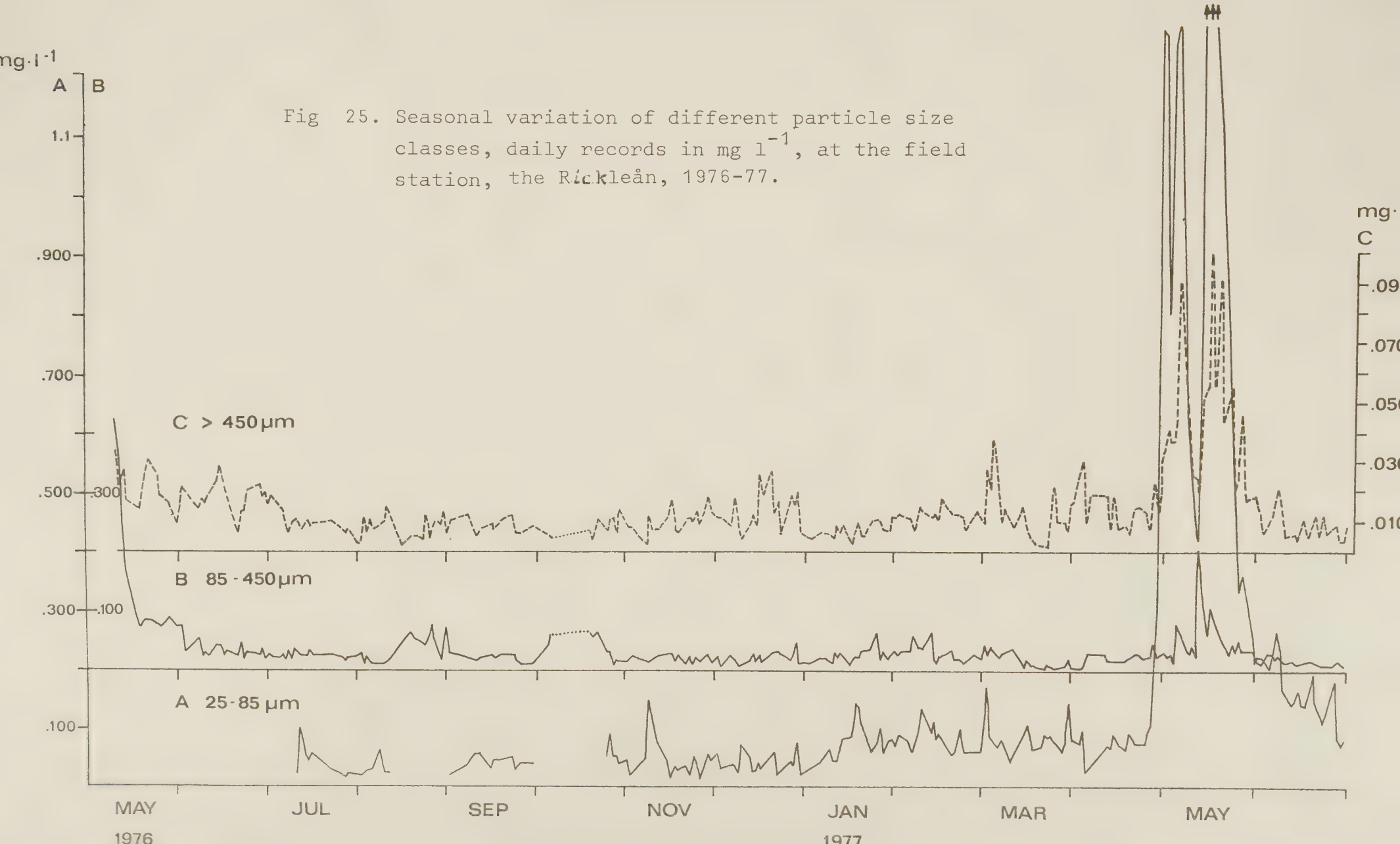


Fig 25. Seasonal variation of different particle size classes, daily records in mg l^{-1}, at the field station, the Rickleån, 1976-77.

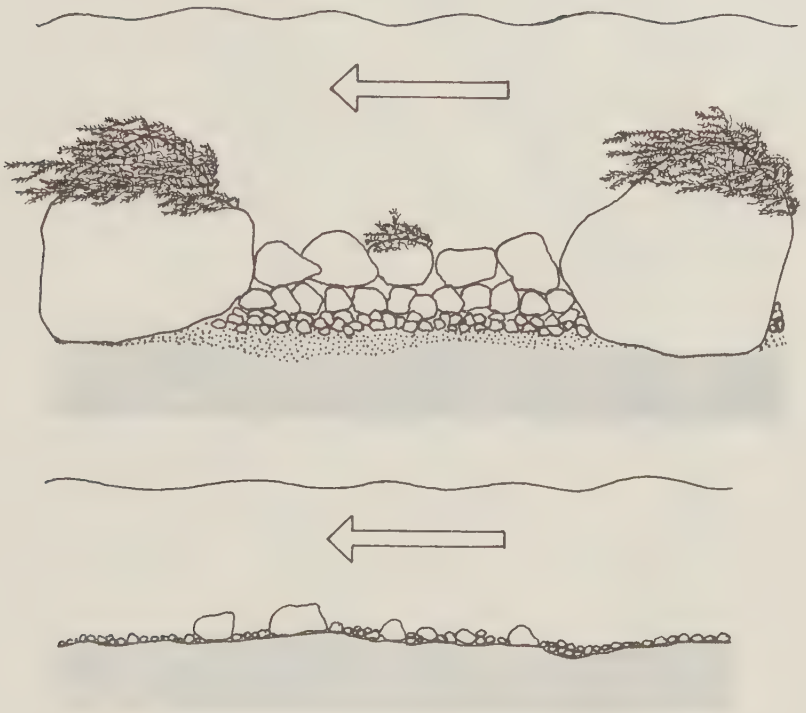


Fig 26. Schematical drawings of two extreme types of stream beds; the multi-layered and the uni-layered, respectively.

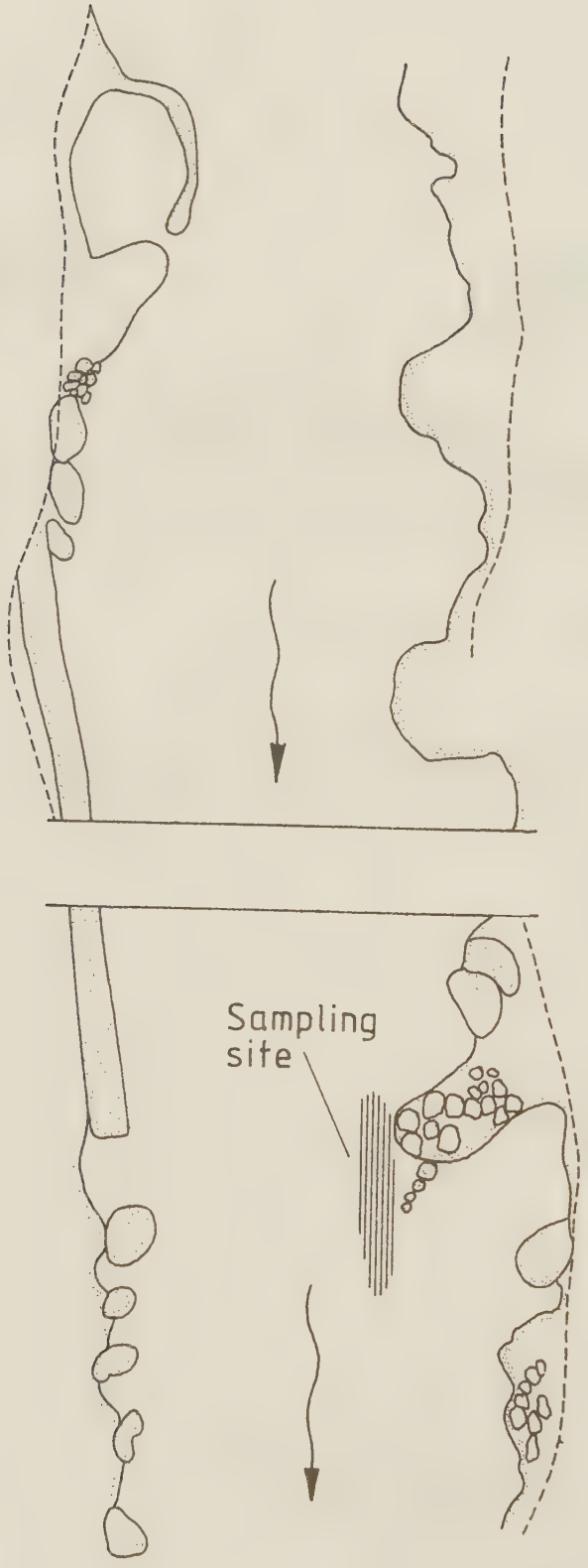


Fig 27. Sampling site (marked area) for the bottom fauna at Storlångforsen 1973-75.

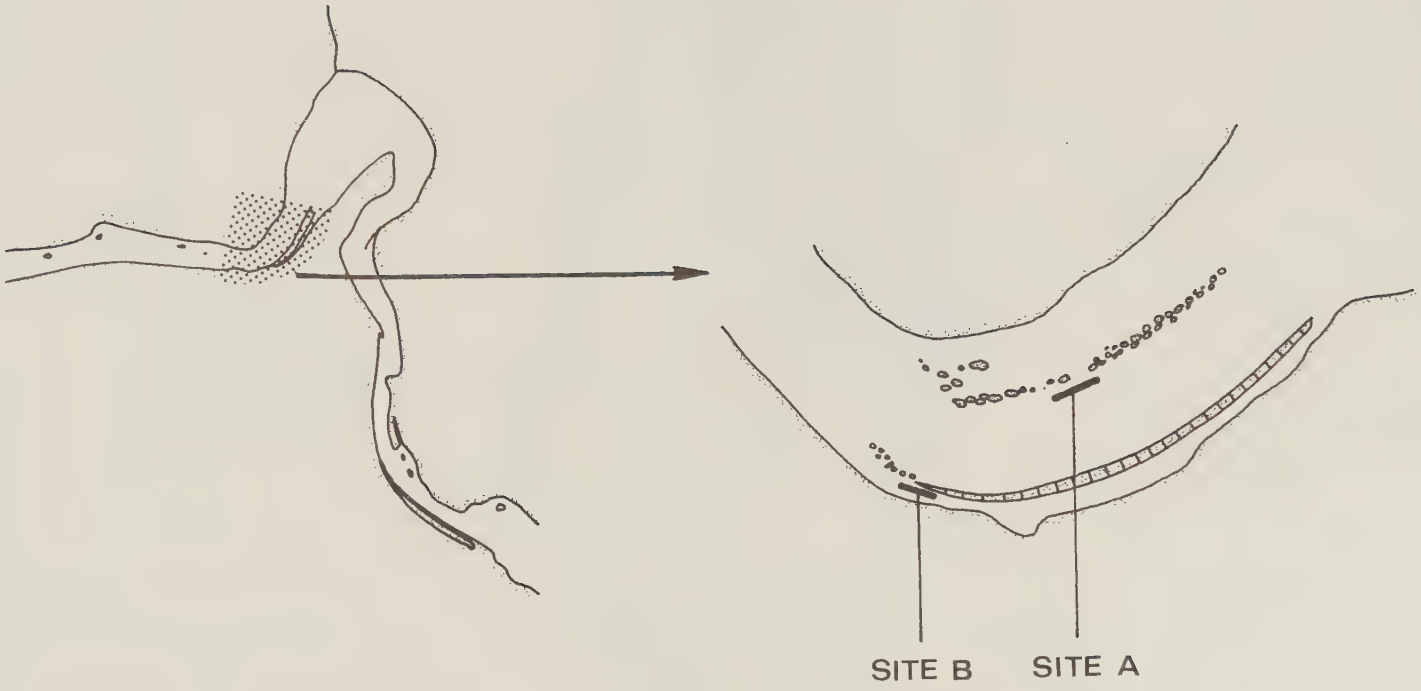


Fig 28. Sampling site (A) for the bottom fauna in Isakfäboda-
forsen 1974-75.

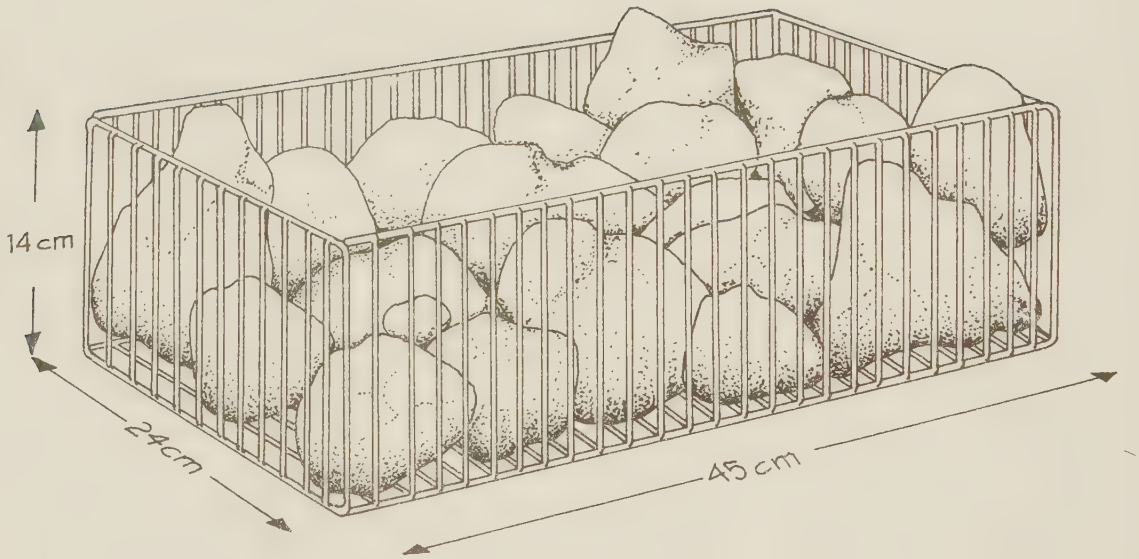


Fig 29. The colonization basket used in the bottom fauna studies.

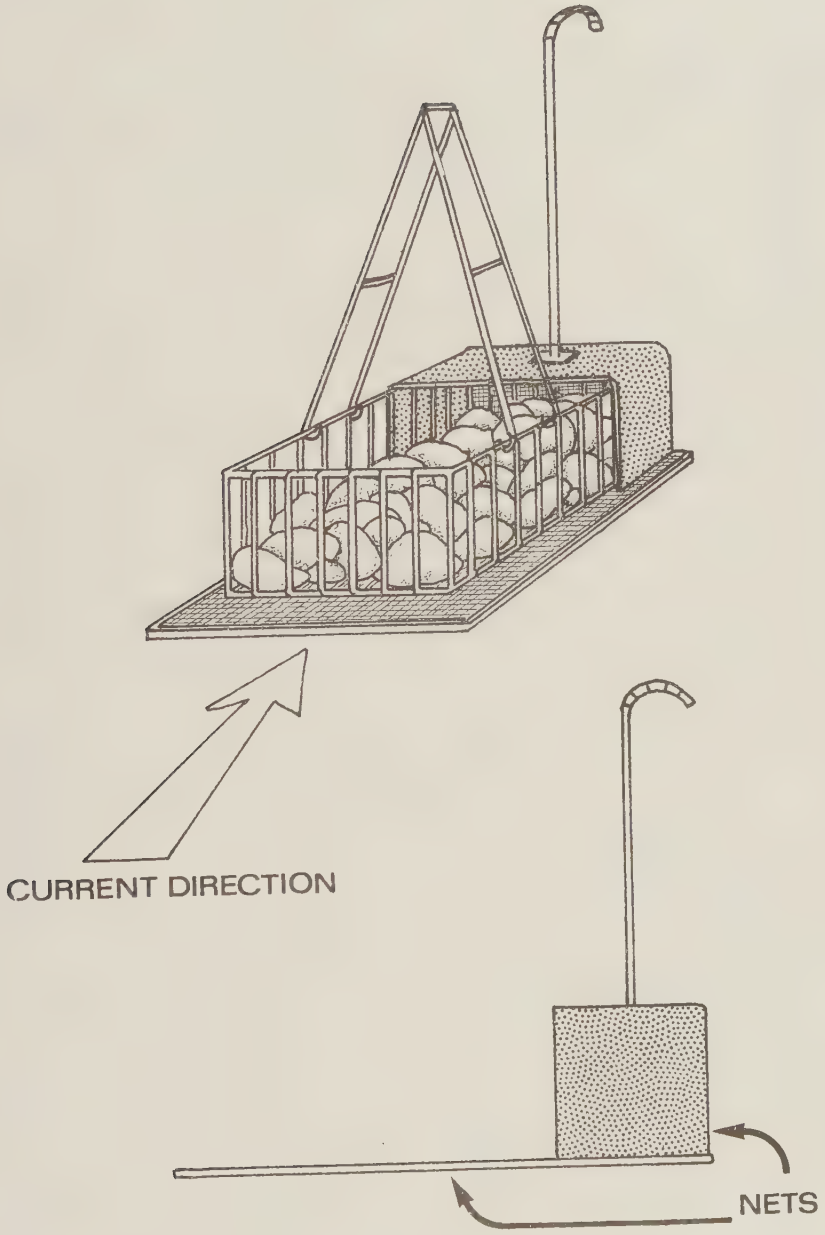


Fig 30. The net construction used when sampling the colonization baskets.

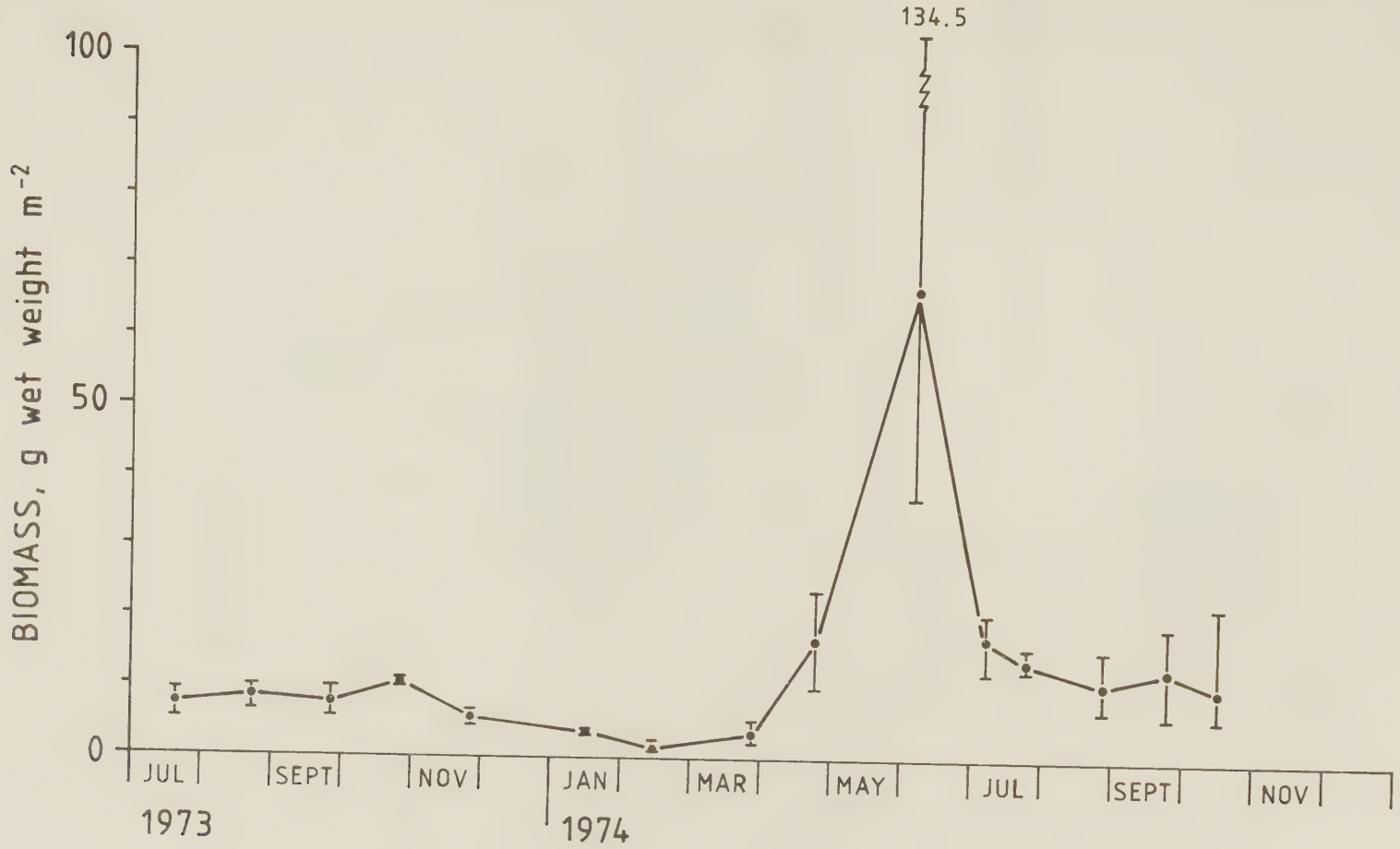


Fig 31. Mean biomass in gram wet weight m^{-2} of the colonization basket at Storlångforsen 1973-74. Horizontal bars indicate the range.

Tab 1. Meterological conditions for the Rickleån drainage basin, given as ranges during the period 1931-60. Data from Taesler (1972) and Ångström (1953).

Mean annual temp, °C	Mean January temp, °C	Mean July temp, °C	Mean annual precipitation in mm	Number of days without frost x)
1 - 2	-7 - -9	15 - 16	500 - 600	160 - 170

x) 1901 - 1930 (Ångström 1953)

Tab 2. Cumulative, monthly precipitation, in mm, at Rickleå field station 1973-76, and as mean for the period 1931-60 for Hällnäs and Umeå.

	Rickleå field station				Hällnäs	Umeå
Month	1973	1974	1975	1976	1931-60	
Jan	15.6	46.0	62.6	34.6	32	49
Feb	49.9	64.2	13.2	37.1	26	30
Mar	36.9	4.7	10.8	37.2	20	26
Apr	81.5	2.6	22.0	10.4	25	34
May	49.5	17.5	45.5	13.6	32	29
Jun	21.4	30.9	45.0	12.3	53	49
Jul	43.8	115.7	3.3	58.9	76	63
Aug	55.1	57.5	71.5	18.6	77	77
Sep	42.5	80.2	82.5	66.5	57	61
Oct	23.7	99.4	35.3	18.4	47	59
Nov	43.3	111.1	38.8	60.2	48	67
Dec	58.5	54.7	51.4	50.4	40	56
Sum	522	685	482	418	533	601

Notes

Umeå 63° 50' N, 20° 17' E, 11 m a.s.l.
Hällnäs 64° 16' N, 19° 38' E, 179 m a.s.l.

Tab 3. Major habitats in the Rickleån and their water velocity, substrate and vegetation.

RAPIDS (water velocity in the channel, 0.8-2 m s^{-1})

(1) The channel: Boulders and large stones, down in the bottom small stones and gravel, larger stones and boulders covered with water mosses, above all *Fontinalis dalecarlica*.
(2) Areas near the banks: Medium sized and small stones, partly exposed, the water mosses restricted, and here *F. antipyretica*.
(3) Dead water areas: Stones, during low water levels deposition areas, no mosses.

STREAMING SECTIONS (w.v. in the channel, 0.4-0.8 m s^{-1})

(1) The channel: Hard bottoms of clay, gravel and small stones, seldom submersed higher vegetation.
(2) The littoral zone: Soft, organic bottoms, strong submersed and emergent vegetation.

SLOW FLOWING SECTIONS (w.v. in the channel, 0.2-0.4 m s^{-1})

(1) The channel: Soft bottoms of sand with a thinn layer on the top of organic sediments, often submersed vegetation.
(2) The littoral zone: Soft, organic bottoms, very strong submersed and emergent vegetation, at some places the river widens and creates river-lake conditions.

Tab 4. Concentration of major constituents from two sampling stations in the Rickleån 1970-75 (meq l^{-1}).

	Robertsfors				Field station			
	mean	SD	$\frac{SD \cdot 100}{\bar{x}}$	%	mean	SD	$\frac{SD \cdot 100}{\bar{x}}$	%
Ca	.166	.013	8.0	49.1	.179	.024	13.2	48.5
Mg	.079	.008	10.3	23.4	.086	.014	16.5	23.3
Na	.070	.008	11.6	20.7	.080	.013	16.1	21.7
K	.023	.004	17.5	6.8	.024	.004	17.5	6.5
Sum	.338			100	.369			100
HCO_3	.099	.017	17.1	30.0	.094	.028	29.5	26.3
SO_4	.194	.023	12.1	58.8	.224	.053	23.5	62.6
Cl	.037	.007	18.4	11.2	.040	.007	16.4	11.2
Sum	.330			100	.358			100

Tab 5. Concentration of NO_2-N + NO_3-N in µg l^{-1} at Robertsfors (A) and the field station (B) in the Rickleån, 1974-76.

Date	A.	B.	Date	A.	B.
1974					
Aug. 8	52		Jun. 1	81	121
Aug. 24	50		Jun. 15	20	47
Sep. 18	42	90	Jul. 1	20	56
Sep. 30	91	96	Aug. 2	32	30
Oct. 4	100	121	Aug. 16	29	14
Oct. 31	110	124	Sep. 1		36
Nov. 15	99	106	Sep. 16	42	102
1975			Oct. 18	67	127
Jan. 17		149	Nov. 1	77	136
Feb. 17		103	Nov. 15	138	160
Feb. 27		137	Dec. 1	88	130
Mar. 14	92	120			
Apr. 1		102			
Apr. 15	93				
May 15	110				
May 28		148			
Jun. 2		129			
Jun. 16	52				
Jul. 16	46				
Aug. 15	39	92			
Sep. 15	28				
Oct. 15	54				
Nov. 14	102				
Dec. 15	71				
1976					
Feb. 16	119				
Mar. 1	127	117			
Mar. 15	102	94			
Apr. 1	106	131			
Apr. 14	151	119			
May 3	113	98			
May 17	127	113			

Tab 6. Concentration of PO_4-P in µg l^{-1} at Robertsfors (A) and at the field station (B) in the Rickleån, 1974-76.

Date	A.	B.	Date	A.	B.
1974					
Nov. 15	3.1	1.9	Aug. 2	(161.2)	7.5
			Aug. 16	3.8	2.8
1975			Sep. 1	2.8	2.8
			Sep. 16	2.8	2.3
Jan. 17		4.1	Oct. 18	20.0	6.8
Feb. 17		8.8	Nov. 1	2.7	3.8
Feb. 27		2.8	Nov. 15	(45.2)	1.9
Mar. 14	1.5	2.2	Dec. 1	3.5	5.1
Apr. 15	1.7				
May 15	1.5				
May 28		3.2			
Jun. 2		1.9			
Jun. 16	4.4				
Jul. 16	2.0				
Aug. 5		2.7			
Aug. 15	1.7				
Sep. 15	5.8				
Oct. 15	3.3				
Nov. 14	3.0				
Dec. 3	3.6	3.6			
Dec. 15	3.8				
1976					
Jan. 15	4.8				
Feb. 16	1.5				
Mar. 1	(40.4)	3.8			
Mar. 15	(146.5)	4.6			
Apr. 1	6.8	7.1			
Apr. 14	4.0	5.6			
May 3	2.6	1.6			
May 17	3.1	1.8			
Jun. 1	2.9	2.3			
Jun. 15	3.4	3.9			
Jul. 1	10.2	3.7			

Tab 7. Turbidity, as NTU, at the Rickleå field station, 1975-76. UF unfiltrated samples, FI filtrated samples, and DIF the difference between UF and FI.

Date	UF	FI	DIF
1976			
Jan. 14	.44	.25	.19
Feb. 1	.55	.26	.29
Feb. 14	.51	.23	.28
Mar. 2	.58	.26	.32
Apr. 20	1.75	.55	1.20
Apr. 22	1.30		
Apr. 28	1.33	.46	.87
May 4	1.17	.41	.76
May 5	1.10	.38	.72
May 7	1.70	.41	1.29
May 9	1.80	.46	1.34
Jun. 1	.96	.43	.53
Jun. 9	.87	.38	.49
Jun. 21	.80	.42	.38
Jun. 30	.98	.40	.58
Aug. 2	.98	.48	.50
Aug. 18	.92	.37	.55
Aug. 31	.88	.37	.51
Sep. 23	.82	.36	.46
Oct. 26	.91	.41	.50
Nov. 21	(1.95)	.50	(1.45)
1977			
Jan. 3	.60	.35	.25
Jan. 18	.62	.31	.31
Feb. 8	.62	.32	.30
Mar. 24	.58	.35	.23

Tab 8. The autumn leaf-fall into the Rickleån from different types of bank vegetation.

Type of bank vegetation	Site	Year of sampling	Leaf-fall		
			$g\ m^{-1}$ shoreline	$g\ m^{-2}$ width: 25 m	$g\ m^{-2}$ width: 40 m
Only Salix shrubs	D	1976	273	11	7
Medium trees + shrubs	C	1976	752	30	19
Below a large tree (probable maximum value)	A	1975	1048	42	26

Tab 9. Surface and near-surface drift of large particulate organic matter at the field station, the Rickleån. Mean hour catch with net (mesh size 0.8 mm). Air-dried, in grams.

Type of matter	mean weight	%	max weight	min weight
June 18-19, 1975				
Equisetum	7.9	51	26.4	0.6
Green leaves	0.1	<1	0.8	0
Twigs, branches	1.7	11	6.5	0
Remaining	5.9	38	14.6	2.2
Total	15.7	100	-	-
June 23-24, 1975				
Equisetum	2.5	18	17.5	0.1
Green leaves	1.0	7	4.1	0.1
Twigs, branches	2.1	15	6.5	0.1
Remaining	8.3	60	38.7	1.1
Total	13.8	100	-	-
June 30-July 1, 1975				
Equisetum	0.5	17	1.5	0.1
Green leaves	0.2	7	0.6	<0.1
Twigs, branches	0.6	18	1.1	0.1
Submersed veg	0.1	2	0.2	<0.1
Salix spp (flowers)	0.2	6	0.4	<0.1
Remaining	1.5	48	2.4	1.0
Total	3.1	98	-	-

Tab 10. Weight loss rates of leaf-packs consisting of old and newly shed leaves (*Populus tremula*), the Rickleån, 1974, (per cent day^{-1}).

		10 g packs [1]		5 g packs [2]	
		Old	New	Old	New
Days	21-23	-	1.23	0.55	1.10
	34-35	-	1.02	-	0.95
	55-56	0.61--0.71	0.70	0.45	-

1) S. Flodin & P. Lundbäck, unpubl. materials

2) Karlström 1976 b

Tab 11. A comparison of weight loss in per cent day^{-1} between data from the Rickleån (I) and calculated data (II-III) of Suberkopp et al. (1975).

Water temperature		Weight loss		
Range in the Rickleån experiment °C	Calculated mean from the cited paper	The Rickleån I	a slow species II	a fast species III
13-15	14	1.03	1.07	2.28
1-9.5	5	1.02	0.45	1.00

Tab 12. Calculated time in days for 90 % weight loss of leaves of different species.

Biome or stream type (reference)	Type of leaf species	Time	
		1)	2)
Western U.S. coniferous forest (Sedell et al. 1975)	fast	182-339	115-137
	slow	960	213
	conifer	921	176
Eastern U.S. deciduous hardwoods (Petersen & Cummins 1974)	fast	<230	
	medium	230-461	
	slow	<461	
Danish springbrook (Iversen 1975)	medium (Fagus)	365	
The River Thames (Mathew & Kowalczewski 1969)	medium	≪365	
	slow	<365	

1) Q_{max} = 0.14 m^3 s^{-1} 2) Q_{max} = 1.8 m^3 s^{-1}

Tab 13. Total amount of organic materials on stones in relation to their volumes, projected surfaces and total surfaces in the Rickleån 1975.

	Soft brushing			Combined brushing		
	Volume	P-surface	T-surface	Volume	P-surface	T-surface
$\bar{x}$	118.0	35.0	11.9	354.8	104.7	34.3
n	19	22	18	19	22	18
SD	35.5	10.5	3.6	108.2	35.7	9.6
$\frac{SD\ 100}{\bar{x}}$	30.1	30.0	29.8	30.5	34.1	28.1
95 % conf. limits	100.7--135.3	30.4--39.6	10.1--13.7	303.0--406.4	89.0--120.4	29.5--39.1

Tab 14. Quantity of the organic layer on stones exposed to natural light condition and darkness, respectively, at the Isakfäboda rapids in the Rickelån. Mean weight in mg $\pm$ SD.

Exposition	weight Volume (dm^{-3})	P-surface (dm^{-2})	N
Light	93.8 ± 17.7	27.9 ± 2.1	3
Dark	70.7 ± 22.3	17.7 ± 3.7	3

Tab 15. Total amount of organic matter on stones at the Nättingforsen in the Rickleån, June 24, 1975. Mg dm^{-2} (P-surface).

Method	$\bar{x}$	n	SD	Confidence limits ($p < 0.05$)
Soft brushing	20.9	5	4.7	15.4 - 26.3
Combined brushing	44.4	5	4.8	38.9 - 49.9

Tab 16. The effect of different factors or components on the development of the organic layer on stones.

Factor or component	Direction of change	Development of the organic layer
A. Primary production	+	+
B. Seston concentration	+	+
C. Growth of fungal tissues	+	?
D. Trapping capacity (=increase of A, B, C)	+	+
E. Turbulence	+	-
F. Grazing	+	-
G. Mineralization	+	-

Tab 17. Comparison of the respiration rates (mg O_2 $mg^{-1}d^{-1}$) of two chambers with different volumes and water velocity (see the text for explanation). Values are given at 20°C (Winberg 1971 a).

	Soft brushing	Combined brushing
Small chambers n = 10	0.275±0.103	0.093±0.028
Large chambers n = 6	0.219±0.107	0.092±0.053

Tab 18. Literature data on community respiration (g O_2 $m^{-2}d^{-1}$) of sediment or benthic substrates in aquatic environments. The data were obtained with different methods and during different temperature intervals.

Mean	Min - Max	Reference
I. Lakes and brackish waters		
-	0.3 - 3.0	Edberg & Hofsten 1973
-	0.26- 1.06	Edberg 1976
-	0.11- 0.14	Granberg 1976
-	0.69- 1.54	Granéli 1976
-	0.14- 1.43	Hargrave 1969
II. Running waters		
-	1.0 - 24.0	Edwards & Rolley 1965
-	0.16- 1.59	James 1974
1.2	0.14- 9.8	Rolley & Owens 1967
1.9	- -	Odum 1957
1.54	- -	Ueda 1975
-	0.17- 1.15	The Rickleån (only the organic layer of the stones)

Tab 19. Total benthic community respiration (g O_2 $m^{-2}d^{-1}$) in the Rickleån 1974-75.

Level	Minimum	Maximum	Reference
Fontinalis	0.7	3.6	Johnsson, in press
The organic layer on stones	<0.17	1.2	present study
Top 4 cm of the hyporheos	0.2	0.7	Robert C. Petersen (pers. comm.)
Total	<1.1	5.5	

Tab 20. Retention capacity of glass fibre filters (mg l^{-1}) in relation to filtrated volume. The Rickleån, March 30, 1976.

Filter volume	Mean	Sampling units
2.0 l	0.23	0.2 - 0.25 - 0.25
1.0 l	0.07	0 - 0.1 - 0.1

Tab 21. Variation of the FPOM content (mg l^{-1}) in groups of 5 samples on different occasions in 1975.

Date	Mean	S.D.	Coefficient of variation
Feb 7	0.82	0.13	15.9
Mar 7	0.86	0.09	10.4
21	1.0	0.07	7.0
Apr 11	1.44	0.23	16.0
May 2	2.44	0.05	2.2
9	1.9	0.1	5.3
23	1.58	0.16	10.4
Jun 6	1.58	0.27	17.0
13	1.24	0.15	12.2
Jul 25	0.86	0.15	17.6
30	0.96	0.05	5.6
Grand mean of the coefficient of variation			10.9

Tab 22. Particles >25 um in relation to the total FPOM concentration at different periods 1976-77 at the field station, the Rickleån. The weights in mg l^{-1}.

Date	Total FPOM	Particles >25 um	% of total	
May 10	2.95	.465	15.8	
11	3.14	.413	13.2	
12	2.60	.360	13.8	
13	1.90	.218	11.5	
14	1.50	.178	11.8	
Jul 12	1.27	.138	10.9	
14	1.30	.093	7.2	
15	1.07	.085	7.9	
16	1.00	.098	9.8	
Sep 23	.69	.091	13.2	
24	.79	.057	7.2	
26	.89	.063	7.1	
30	.86	.061	7.1	
Nov 8	.90	.075	8.3	
9	1.35	.174	12.9	
10	2.25	.154	6.8	
12	3.13	.112	3.6	1)
15	1.55	.088	5.7	
1977				
Jan 19	1.40	.182	13.0	
20	1.30	.166	12.8	
21	1.53	.150	9.8	
24	1.83	.107	5.8	
Mar 30	.40	.084	21.0	
31	.60	.154	25.7	
Apr 1	.50	.103	20.6	
4	.40	.109	27.3	
5	.47	.110	23.4	
6	.67	.076	11.3	
May 13	4.59	1.784	38.9	
16	4.40	2.491	56.6	
17	5.20	1.905	36.6	
18	5.70	2.160	37.9	
Jun 1	1.40	.258	18.4	
2	1.35	.243	18.0	
3	1.60	.230	14.4	

1) High silt load due to construction work in the river

Tab 23. Load of different FPOM fractions in mg l^{-1} from the Rickleån.

Fraction	Minimum	Maximum	Max/min
>450 µm	0.003	0.092	30
85-450	0.006	0.430	70
25-85	0.017	2.332	140
1-25	0.291	3.54	12
Filter	0.2	5.7	30

Tab 24. Diel variation of the FPOM concentration (mg l^{-1}) in the Rickleån. Mean and, within brackets, sample values.

I July 4-5, 1974		
Time	Robertsfors	Field station
12	1.47 (0.8-1.5-2.1)	1.5 (1.5-1.5)
16	1.5 (1.4-1.6)	1.5 (1.4-1.6)
19	1.3 (1.3-1.3)	1.3 (1.2-1.4)
08	-	1.35 (1.3-1.4)
11	-	1.4 (1.2-1.6)

II July 10-11, 1975		
Time	Robertsfors	Field station
12	1.0 (1.0-1.0)	1.45 (1.3-1.6)
16	1.0 (1.0-1.0)	1.4 (1.2-1.6)
20	0.95 (0.9-1.0)	1.5 (1.5-1.5)
24	1.05 (1.0-1.1)	1.1
04	1.0 (1.0-1.0)	1.45 (1.4-1.5)
08	1.5 (1.2-1.8)	1.7
mean	1.08	1.43
s.d.	0.21	0.19
var. in %	19.1	13.5

III September 16-17, 1975	
Time	Field station
07	0.97 (0.93-1.0)
13	0.97 (0.93-1.0)
16	1.27 (1.25-1.28)
07	0.97 (0.93-1.0)
16	0.97 (0.93-1.0)

Tab 25. FPOM concentrations (mg l^{-1}) at two stations in the Rickleån, 1974. The samples were taken within two hours, mostly 3 to 5 p.m.

Date		Isakfäbodaforsen	Field station
Apr	17	1.7	2.0
	19	1.7	3.5
	24	1.4 (1.4/1.6)	2.2
May	23	1.1 (1.1/1.1)	1.0 (0.9/1.1)
Jun	20	0.85 (0.7/1.0)	0.7
Jul	1	1.15 (1.0/1.3)	0.93 (0.7/1.0/1.1)
	6	1.05 (0.8/1.3)	1.2 (1.1/1.3)
	16	3.4 (3.2/3.6)	3.1 (2.8/3.4)
Aug	12	1.1 (1.0/1.2)	1.45 (1.3/1.6)
	15	1.75 (1.7/1.8)	1.55 (1.5/1.6)
	21	0.65 (0.6/0.7)	1.45 (1.3/1.6)
Sep	18	1.06 ± 0.09 (5) x)	1.28 ± 0.22 (5) x)
	27	0.5	2.1 (1.8/2.4)
Oct	4	1.80 (1.8/1.8/1.8)	3.12 (2.7/3.2/3.4)
Sum		19.2	25.6
Mean		1.37	1.83

x) $\bar{X} \pm SD$ (n)

Tab 26. Cumulative FPOM concentrations (mg l^{-1}) from monthly sampling at different rapids along the Rickleån, 1974-76. n = number of monthly samples during a year.

	Faran-forsen	Isakfäboda-forsen	Johanne-lund	Lax-backen	Gamm-strömmen
1974					
Sum	11.7	12.2	12.7	10.7	(12.3)
n	11	11	11	11	9
1975					
Sum	10.0	10.8	11.6	11.8	12.6
n	11	11	11	11	11
1976					
Sum	11.1	10.7	14.0	12.1	(9.6)
n	11	11	11	11	8

Tab 27. The FPOM load of various streams reported by different authors.

Name	Reference	Discharge, $m^3 s^{-1}$			FPOM-load, $mg\ l^{-1}$			Methods	
		min	max	mean	min	max	mean or mode	wet oxi-dation	loss on ignition
Sugebaeck	Madsen 1972	0	-	-	-	2.3	1	X	
Catahoula creek	de la Crus & Post 1977	2nd order stream			3	11.9	-		X
Wisconsin river	Birge & Juday 1926	-	-	-	1.0	2.6	-		X[1)]
Inlet to ö. Heimdalsvann	Larsen & Tangen 1975	-	-	-	-	9.5	0.4-0.95		X
Boulder Creek	Pennak 1943	0.03	9.4	-	10	24	-		X[2)]
Palouse River	Buscemi 1969	-	-	-	0.8	4.6	2.5		X[1)]
Convict creek	Maciolek 1966	0.2	3.4	-	0.3	2.1	0.7	X	
Bear Brook	Fisher & Likens 1973	0.002	1.0	-	-	3.0	0.25	X	
Roaring Brook	McDowell & Fisher 1976	0.002	0.122	0.019	0.04	3.2	0.16	X	
Several Canadian stream	Hynes et al. 1974	-	-	-	1	60	-	-	-
Bere Stream	Ladle et al. 1972	0.28	2.5	0.70	1.1	42	-		X
The Thames	Berrie 1972	3.7	185	-	2.6	40.8	-		X
Middle Ocone River	Nelson & Scott 1962	0.8	194	8.1	0.6	90	2-6		X[1)]
The Öre River	Nilsson 1972 + pers comm. SMHI	4	300	28	1.9	12.6	2-3		X
The Rickleån	Present study	3	170	16	0.2	5.7	1		X

1) Centrifuging + loss on ignition 2) Evaporation + loss on ignition

Tab 28. Percentage loss of individuals of benthic invertebrates from colonization baskets in the Rickleån 1974-75. See text for explanation.

Taxa	loss percentage			
	Mean	±SD	n	range
Asel aqu	+		7	
Baet spp	21.5	24.4	14	1.6 - 92.9
Ephe ign	2.5	3.6	4	0 - 7.1
Ephe muc	30.4	23.7	9	2.6 - 59.5
Hept dal	8.8	9.1	10	0 - 18.1
Taen neb	+		6	
Isop sp	10.0	10.4	4	0 - 23.1
Prot mey	0		2	
Diur nan	0		6	
Leuc sp	0		3	
Amph sp	24.3	22.0	7	0 - 52.4
Rhya nub	2.5	4.4	13	0 - 12.5
Hydr nev	5.7	7.9	8	0 - 18.2
Hydr ins	10.1	16.3	6	0 - 42.9
Arct lad	1.3	2.6	7	0 - 6.7
Chey lep	0		7	
Glossomx	5.6		3	0 - 16.7
eruc. tric.	+		10	
Elmi aen	15.1	19.6	7	1.6 - 54.5
Chir	4.5	4.6	14	0.2 - 17.5
Sim	2.0	2.0	14	0 - 7.0
Ancy flu	+		2	
Lymn per	+		5	
Total	2.8	2.0	14	0.5 - 7.0

Tab 29. Percentage loss of biomass of the benthic invertebrates from colonization baskets in the Rickleån 1974-75. See the text for explanation.

Taxa	loss percentage			
	Mean	±SD	n	range
Turb	0		2	
Olig	+		3	
Asel aqu	+		4	
Baet spp	40.5	34.0	7	17.8 - 113
Ephe muc	29.1	24.2	7	2.8 - 67
Hept dal	5.5	3.8	6	0 - 8.1
Taen neb	+		3	
Isop gram	16.6	23.5	7	0 - 60
Diur nan	0		3	
Leuc sp	0		3	
Amph sp	33.4	26.1	7	2.7 - 57
Rhya nub	2.2	4.4	8	0 - 11.7
Hydr nev	3.7	5.7	8	0 - 11.0
Hydr ins	1.8	3.6	6	0 - 7.2
Arct lad	2.0	2.3	7	0 - 7.0
Cheu lep	0		7	
Elmi aen	16.3	17.5	6	0 - 27.8
Chir	3.9	6.8	7	0.3 - 17.7
Sim	2.5	2.0	8	0.8 - 5.3
Total	4.2	2.5	8	1.3 - 7.9

baskets) from Isakfäbodaforsen, July 22, 1974. Biomass in mg wet weight m^{-2}, unless stated otherwise.

Taxa	Sample no					
	1	2	3	4	5	mean
Olig	10	41				10
Asel aqu				6	4	
Baet spp	483	88	222	179	255	245
Ephe ign	1678	642	854	738	1437	1070
Hept dal	887	303	418	767	597	594
Diur nan	-	-	20	32	22	15
Leuc sp	90	73	42	22	58	57
Rhya nub	353	892	555	569	324	539
Hydr nev	95	141	252	250	215	191
Hydr ins	58	1026	649	714	867	663
Arct lad	1732	1170	3903	1812	1962	2116
Chey lep	23	-	-	-	-	5
Cyrn fla	66	66	97	-	45	55
camp Tri	-	-	-	-	43	9
Eomy int	1312	656	108	1342	1266	937
Lepi sp	51	5	28	15	20	24
eruc Tri	2641	5	512	30	160	669
Elmi aen	119	45	47	35	75	64
Limn vol	-	-	-	-	15	3
Chir	451	463	411	499	475	460
Sim	316	740	4173	1036	2256	1704
Ancy flu	19	117	269	313	156	175
Lymn per	195	183	218	464	677	347
Biomass g ww m^{-2}	10.6	6.7	12.8	8.8	10.9	10.0
CPOM removed, g	2.8	18.7		17.0	20.4	
CPOM in the sample, g	7.3	6.1	8.0	2.3	3.7	

Notes

camp Tri = remaining campodeiforma Trichoptera, eruc Tri = remaining eruciforma Trichoptera.

CPOM removed = CPOM that have been stuch in the sides of the colonizations basket.

The amount of CPOM is given as dry weight.

Tab 31. List of benthic macro-invertebrates, sampled with colonization baskets in the channel zone of the rapids and records from other habitats (some exclusively lentic forms are omitted). 0 not found; (+) very rare; + not common; ++ common; +++ very common. L, larvae and I, imagines.

	Found in the channel zone	Found in other habitat in or along the Rickle	
	ABUN	ABUN	STAGE
Turbellaria /nfd/	(+)	+	
Oligochaeta /nfd/	+	+/+++	
Hirudinea			
Helobdella stagnalis (L.)	0	+	
Erobdella octoculata (L.)	0	+	
Hydracarina /nfd/	+	+/++	
Isopoda			
Asellus aquaticus L.	+	+/++	
Amphipoda			
Pallasea quadrispinosa Sars	0	(+)	
Ephemeroptera			
Ephemera danica Müll.	0		I
" vulgata L.	(+)	++	LI
Siphlonurus alternatus Say	0		LI
" sp.	0	(+)	L
Baetis buceratus Etn.	?	+++	LI
" niger L.	?		L
" rhodani Pict.	?		LI
" muticus L.	?		L
" subalpinus Bgtss.	?		I
" spp.	+++	+++	L
Cloeon dipterum L.	0		L
Procloeon bifidum Bgtss.	0	(+)	LI
Centroptilum luteolum Müll.	(+)	(+)	LI
Metretopus borealis Etn.	0		LI
Heptagenia dalecarlia Bgtss.	+++	++	LI
" fuscogrisea Retz.	0	+	LI
" sulphurea Müll.	?	+	L
Leptophlebia marginata L.	0	+	LI
" vespertina L.	0		LI
Paraleptophlebia sp.	(+)		L

Ephemerella aurivillii Bgtss.	(+)	+	LI
" ignita Poda	+++	+++	LI
" mucronata Bgtss.	+++	+++	LI
Plecoptera			
Taeniopteryx nebulosa L.	+++	++	LI
Amphinemura borealis Mort.	++	++	LI
" sulcicollis Steph.	(+)	+	LI
Nemoura avicularis Mort.	0		LI
" cinerea Retz.	0		LI
Protonemoura meyeri Pict.	++	++	LI
Leuctra fusca L.	+	++	LI
" hippopus Kmp.	(+)		LI
Capnia atra Mort.	0		I
Capnopsis schilleri Rost.	0		I
Diura nanseni Kmp.	+	+	LI
Isoperla grammatica Poda	+	++	LI
Siphonoperla burmeisteri Pict.	0	++	LI
Odonata			
Calopteryx virgo (L.)	0		I
Cordulegaster boltoni (Donov.)	0		I
Coleoptera			
Gyrinus sp.	(+)		L
Hydroporus sp.	0		L
Ilybius sp.	0		L
Dytiscus sp.	0		L
Elmis aenea Ph.Müll.	++		LI
Limnius volckmari Panz.	(+)		L
Oulimnius tuberculatus Ph.Müll.	+		L
Megaloptera			
Sialis lutaria L.	0	+	LI
Trichoptera			
Agraylea cognatella McL.		(+)	I
" sexmaculata Curt.		(+)	I
Ithytrichia lamellaris Eat.		++	LPI
Stactobiella risi (Felber)		++	I
Oxyethira flavicornis Pict.			I
" frici Klap.			I
" tristella Klap.			I

Hydroptila angulata Mos.			I
" cornuta Mos.			I
" forcipata (Eat.)		(+)	I
" simulans Mos.			I
" sparsa Curt.			I
" tineoides Dalm.			I
" vectis Curt.		(+)	I
" spp.	+		
Rhyacophila fasciata Hag.		(+)	I
" nubila (Zett.)	+++	++	LPI
Synafophora nylanderi (McL.)		(+)	I
Eomystra intermedia (Klap.)	+++	++	LPI
Agapetus ochripes Curt.	+++	+++	LPI
Wormaldia subnigra McL.		++	LPI
Neureclipsis bimaculata (L.)			I
Plectrocnemia conspersa (Curt.)			I
Polycentropus flavomaculatus (Pict.)	++	++	LPI
" irroratus (Curt.)			I
Holocentropus dubius (Ramb.)			I
" insignis Mart.			I
" picicornis (Steph.)			I
Cyrnus flavidus McL.	+		LI
" trimaculatus (Curt.)			I
Lype phaeopa (Steph.)			PI
Tinodes waeneri (L.)			PI
Psychomyia pusilla (Fbr.)			I
Hydropsyche angustipennis (Curt.)		(+)	I
" instabilis (Curt.)	+++		LPI
" nevae Kol.	+++		LPI
" pellucidula (Curt.)	+		LI
Cheumatopsyche lepida (Pict.)	++		LI
Arctopsyche ladogensis Kol.	+++		LPI

Molanna angustata Curt.	+		LI
Molannodes tinctus (Zett.)			I
Athripsodes albifrons (L.)			I
" alboguttatus (Hag.)			I
" annulicornis (Steph.)			I
" aterrimus (Steph.)		(+)	I
" cinereus (Curt.)			I
" commutatus (Rstck.)			I
" dissimilis (Steph.)			I
" excisus (Mort.)			I
" nigronervosus (Retz.)			I
" perplexus (McL.)			I
Mystacides azureus (L.)			LI
" longicornis (L.)		(+)	I
" niger (L.)		(+)	LI
Trianodes bicolor (Curt.)		(+)	I
" simulans Tjed.			I
Oecetis lacustris (Pict.)			
" ochracea (Curt.)			
" testacea (Curt.)			
Brachycentrus subnubilus Curt.	+	+/+++	LPI
Micrasema gelidum McL.	+	(+)	LI
Lepidostoma hirtum (Fbr.)	+	+	LI
Sericostoma personatum (Spence)	+	+	LPI
Goera pilosa (Fbr.)		+	LI
Apatania wallengreni McL.			I
Parapatania stigmatella (Zett.)			I
Limnephilus auricula Curt.			I
" binotatus Curt.		(+)	I
" borealis (Zett.)			I
" centralis (Curt.)		(+)	I
" coenosus (Curt.)			I
" decipiens (Kol.)			I
" elegans Curt.		(+)	I
" externus Hag.			I
" extricatus McL.			I
" femoratus Zett.			I

Limnephilus flavicornis (Fbr.)		I
" fuscicornis (Ramb.)		I
" griseus (L.)		I
" lunatus Curt.		I
" marmoratus Curt.		I
" nigriceps (Zett.)		LI
" pantodapus McL.		I
" politus McL.		I
" rhombicus (L.)	+	LPI
" sericeus (Say)		I
" sparsus Curt.		I
" stigma Curt.	(+)	I
" vittatus (Fbr.)		I
Grammotaulius nigropunctatus (Retz.)		I
Glyphotaelius pellucidus (Retz.)		I
Nemotaulius punctatolineatus (Retz.)		I
Phacopterys brevipennis (Curt.)		I
Anabolia concentrica (Zett.)		I
" nervosa (Curt.)		I
Lenarchus productus (Mort.)		I
Rhadicoleptus alpestris (Kol.)		I
Potamophylax cingulatus (Steph.)		I
" latipennis (Curt.)	+	LPI
Micropterna lateralis (Steph.)		I
" sequax McL.		I
Hydatophylax infumatus McL.		I
Halesus radiatus (Curt.)	+	LI
" tesselatus (Ramb.)		I
Chaetopteryx villosa (Fbr.)		I
Phryganea bipunctata Retz.		I
" grandis L.		I
Agrypnia obsoleta (Hag.)		I
" pagetana Curt.		I
" principalis (Mart.)	(+)	I
" varia (Fbr.)		I

Diptera			
Limoniidae /nfd/	(+)		L
Simuliidae /nfd/	+++		LPI
Chironomidae /nfd/	+++		LI
Ceratopogonidae /nfd/	+		LI
Empididae /nfd/	(+)		LI
Gastropoda			
Lymnaea peregra Müll.	++	++	
Physa fontinalis L.	0		
Gyraulus acronicus Fer.	0		
Ancylus fluviatilis Müll.	++	+	
Lamellibranchiata			
Sphaerium spp.	0	++	
Pisidium spp.	0	++	

Tab 32. The proportion of all filtraters and the two filter-feeder components to the stone fauna community in the Rickleån 1973-74, on a biomass basis, g wet weight m^{-2}. Net-Trich means net-spinning Trichoptera.

Sampling occasion	Biomass		Percentage		
	Total	Filtraters	All filtraters	only net-Trich.	only Simuliidae
Jul	7.33	4.94	67.4	12.7	54.7
Aug	8.21	5.39	65.7	42.4	23.3
Sep	7.61	4.28	56.2	37.6	18.6
Oct	10.83	6.02	55.6	34.6	21.0
Nov	5.62	1.0	17.8	16.5	1.3
Jan	3.61	0.65	18.0	3.1	14.9
Feb	1.53	0.31	20.3	1.9	18.4
Mar	3.47	1.35	38.9	5.6	33.3
Apr	17.0	13.38	78.7	1.1	77.6
Jun	66.97	53.36	79.7	1.8	77.9
Jul	17.4	15.01	86.3	5.9	80.4
Jul	13.89	10.86	78.2	32.0	46.2
Aug	10.84	8.48	78.2	26.9	51.3
Sep	13.33	10.32	77.4	53.6	23.8
Oct	10.0	5.42	54.2	42.2	12.0

Note

Filter-feeders: *Hydropsyche instabilis, H. nevae, H. pellucidula, Arctopsyche ladogensis, Cheumatopsyche lepida,* Polycentropidae, Simuliidae.

Tab 33. Comparison of the biomass of the bottom fauna (g ww m^{-2}) in two rapids in the Rickleån, July, 1974.

Taxa	Isakfäboda rapids, n = 5		Storlångforsen, n = 5	
	mean	range	mean	range
Olig	10	0-41	-	
Hydrac	-		1	0-6
Asel aqu	2	0-6	-	
Baet spp	245	88-443	167	122-240
Ephe ign	1070	642-1678	555	51-1709
Hept dal	594	303-887	168	18-303
Taen neb	-		2	0-4
Diur non	15	0-32	22	9-31
Leuc sp.	57	22-90	7	0-24
Rhya nub	539	324-892	1373	823-2428
Hydr nev	191	95-252	2436	1720-2960
Hydr ins	663	58-1026	756	429-1006
Arct lad	2116	1170-3903	1236	797-2190
Cheu lep	5	0-23	15	0-74
Cyrn fla	55	0-97	-	
Eom int	937	108-1342	-	
Lepi sp.	24	5-51	-	
eruc. Tric.	669	5-2641	256	0-1206
Chir	460	411-499	340	181-838
Sim	1704	316-4173	6413	5156-7903
Elmi aen	64	35-119	110	71-148
Ancy flu	175	19-313	-	
Lymn per	347	183-677	44	0-161
Remaining	12	0-58	-	
Total	9970	6720-12780	13890	12920-15750
CPOM, front, g	14,7	2,8-20,4	10,3	2,2-18,8
CPOM, sample, g	5,5	2,3-8,0	4,7	0,8-14,1

Tab 34. Comparison of the biomass of the bottom fauna (g ww m^{-2}) in two rapids in the Rickleån, August, 1974.

Taxa	Isakfäboda rapids, n = 3		Storlångforsen, n = 4	
	mean	range	mean	range
Turb	17	0-38	0.3	0-1.2
Olig	24	9-44	13	1-29
Asel aqu	0.3	0-1	23	0-76
Baet spp	414	345-506	138	100-191
Ephe ign	35	29-44	-	
Ephe muc	47	11-76	12	2-29
Hept dal	710	567-899	395	267-441
Taen neb	28	12-38	6	0-13
Isop gra	3	1-6	2	1-4
Diur nan	119	69-170	62	32-141
Leuc sp	8	0-13	1	0-3
Amph bor	0.7	0-1	0.3	0-1.3
Rhya nub	900	497-1583	1746	1417-2112
Hydr nev	373	200-525	691	113-2043
Hydr ins	22	11-43	1353	509-3640
Arct lad	2823	1424-3879	867	681-1113
Cheu lep	6	0-19	8	0-29
Eom int	579	309-721	-	
eruc. Tric.	43	9-70	6	0-19
Chir	550	301-823	180	127-235
Sim	4740	2307-7880	5557	3081-7467
Elmi aen	53	8-127	18	6-29
Ancy flu	135	82-263	-	
Lymn per	87	7-165	11	0-18
remaining	99	2-263	13	6-21
TOT	11848	7389-16585	10840	6830-15650
CPOM, front, g	9.3			
CPOM, sample, g			2.6	1.4-3.5

Tab 35. Comparison of the biomass of the bottom fauna (g ww m^{-2}) in two rapids in the Rickleån, September, 1974.

Taxa	Isakfäboda rapids, n = 5		Storlångforsen, n = 5	
	mean	range	mean	range
Turb	7	0-27	27	0-89
Olig	4	0-12	9	0-24
Hydrac	0.4	0-1	1	0-6
Asel aqu	-		65	0-125
Baet spp	465	269-616	523	278-731
Ephe muc	76	6-172	338	76-596
Hept dal	783	499-1451	454	240-657
Taen neb	78	27-170	120	41-190
Isop gra	11	0-20	20	0-65
Prot mey	6	0-32	6	0-19
Diur nan	35	0-102	186	36-313
Leuc sp	1	0-2	5	0-24
Amph sp	1	1-2	5	0-12
Rhya nub	161	18-341	874	574-1109
Hydr nev	481	303-610	1848	307-3016
Hydr ins	105	0-344	3782	424-6495
Arct lad	1430	851-1867	1455	310-4356
Cheu lep	-		61	3-273
Micr gel	-		2	0-6
eruc. Tric.	62	1-120	25	3-70
Chir	83	12-190	291	62-596
Sim	1197	556-1787	3172	2110-4045
rem. Dipt	-		17	0-55
Elmi aen	4	0-13	33	23-48
Ancy flu	130	13-285	-	
Lymn per	196	0-509	13	0-54
Tot, g m^{-2}	5.3	4.0-6.7	13.3	6.2-19.4
CPOM, front, g	11.3	4.0-18.9	17.0	0-29.9